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The American Midland Naturalist

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VOL. X. JULY, 1927. No. 10.

CONTRIBUTIONS TO THE BOTANY OF MICHIGAN, NO. 13

Notes on Grasses of Michigan and some others.

OLIVER ATKINS FARWELL

Bromus ramosus Huds. Rough Chess. This is the *B. asper* Murray. In the herbarium of *Parke, Davis & Co.*, there is a sheet of this grass from Michigan, without locality, collected by Dr. H. H. Rusby in August, 1884.

Eragrostis Eragrostis (Linn) MacM. Stink Grass. This species has a voluminous synonymy but it is not at all unique in this respect. *E. major* and *E. minor* were united by Trinius under *E. major* and this procedure was followed by others. Under the International Rules, *E. major* must be taken and maintained as the type of the united species; but *major* is not the oldest or proper specific name. Under the International Rules the proper binomial is *E. multiflora* (Foersk.) Aschers, since the earlier *E. multiflora* (Roxb.) Trin. is only a synonym of *E. rubens* (Lam.) Hochst. The designation at the head of this paragraph, however, is the proper name for those who have no objections to the use of duplicate names. *E. Eragrostis* (Linn) Karst. is an earlier name but it also is reduced to synonymy when *E. major* and *E. minor* are united. MacMillan's name is based upon *Briza Eragrostis* Linn, Sp. Pl. 1 (1753) I 70, while Karsten's name is based upon *Poa Eragrostis* Linn, l. c., 68. The plant is often low and geniculate, some of the culms prostrate and matting. Panicles close and compact. Shelbyville No. 5952, July 31, 1921; Ypsylanti, No. 1201, August 12,

1891; Detroit, No. 1201a, August 26, 1892; Parkedale, No. 3007, August 4, 1912.

Eragrostis Eragrostis subvar. *Leersioides* (Presl.) N. Comb. *Eragrostis multiflora* var. *Leersioides* (Presl.) Richter. *Poa Cilianensis* All., Fl. Pied. (1785) II 246 and III t. 91. f. 2. Usually taller and less geniculate, panicle loose, open, spikelets fewer-flowered often only 2 or 3 flowered. Shelbyville, No. 5953, July 31, 1921.

Eragrostis Eragrostis var. *microstachya* (Coss. & Germ.) N. Comb. *E. vulgaris* b. *microstachya* Coss & Germ., Fl. Par. (1845) II 241. *E. minor* Host. Spikelets narrower and more loosely flowered than in the typical form of the species. Detroit, No. 1944-½, August 23, 1905.

Eragrostis spectabilis (Pursh) Steud. *Er. pectinacea* var. *spectabilis* A. Gr. Pursh's name is the oldest valid name applicable to this species. In the typical form the sheaths are glabrous.

Eragrostis spectabilis var. *sparsihirsuta* N. Var. Sheaths more or less hirsute or villous. This is the *Eragrostis pectinacea* Nees, Steud., A. Gr., etc., but not the *Poa pectinacea* Mx. whose name they misapplied.

Eragrostis pilosa (Linn) Beauv. An annual introduced from Europe. Widely distributed. Detroit No. 1560, September 20, 1896; Monroe, No. 6696, August 22, 1923; Detroit (Redford) No. 7241, October 8, 1924.

Eragrostis pilosa (Linn) Beauv., var. *Caroliniana* (Spr.) Farwell. *Poa pectinacea* Mx., Fl. Bor. Amer. (1803) I 69. *P. Caroliniana* Spr. *E. Purshii* (Bernh.) Schrad. Undoubtedly the *Poa pectinacea* of Michaux is the plant that has been known generally as *E. Purshii*. Michaux's plant came from Illinois and he described it as an annual with the palets persistent on the rachis after the falling of the seeds and lemmas. No other plant answers as well to this character which is the one that gave rise to the specific name. It is not observed, or rarely so, in the species (which is a perennial) to which Nees, Steudell, A. Gray and others misapplied Mich-

aux's name; in that the rachis breaks up and the flower falls away with its section. This is scarcely varietally distinct from the European *Eragrostis pilosa* (Linn) Beauv. It is one of our common grasses in waste grounds and old fields that were once cultivated. Detroit, No. 1437, September 2, 1893; Monroe Piers, No. 4563, September 9, 1917; River Rouge, No. 5144, September 15, 1918; Detroit, No. 5144a, September 15, 1919; Detroit (Oakwood) No. 5133, September 15, 1918; Royal Oak, No. 5589d, August 12, 1920; Shelbyville, No. 5955, July 31, 1921; Monroe, No. 6719, August 22, 1923; Whitmore Lake, No. 6774, September 5, 1923; La Salle, No. 7182, September 17, 1924; Flat Rock, No. 7495, July 29, 1925. Also collected at Chicago, Ill., No. 5097, August 20, 1918.

Eragrostis amabilis (Linn) O. K., Rev. Gen. Pl. (1891) I 773-'4. *Poa amabilis* Linn, Sp. Pl. Ed. I (1753) I 68. *E. tenella* (Linn) Beauv. ex. R. & S., Syst. (1817) II 576 not *Poa tenella* Linn., Sp. Pl. Ed. 1 (1753) I 69. *E. plumosa* (Retz) Link, Hort. Berol. (1827) I 192. In the first edition of the Species Plantarum, Linn described *Poa amabilis* (=*P. plumosa* Retz) and *P. tenella* (=*P.Japonica* Thurb.) In later publications as pointed out by Otto Kuntze he revised his description of *P. tenella* and included various synonyms so that it became an aggregate including his *P. amabilis* which he also maintained separately, thus making confusion worse confounded. The *E. tenella* Beauv. ex R. & S. was based on the revised aggregate species, *P. tnella* Linn, Sp. Pl. Ed. 2 (1762) I 101, and threfore is not tenable on account of its having been interpreted as applying to the same species as the *P. amabilis* of the first edition. The earlier *E. amabilis* W. & Arn. ex Hooker & Arnott cannot interfere with the adoption of Kuntze's name for the *E. plumosa*, since it is but a synonym for *E. rubens* (Lam.) Hochst.; also, it was based on the *Poa amabilis* with 18-flowered spikelets of the systema Ed. XII, and therefore is untenable.

Eragrostis tenella (Linn) Beauv. ex. Benth., Fl. Hongk. (1861) 431; O. K., Rev. Gen. Pl. (1891) I 774. *Poa tenella* Linn, Sp. Pl. Ed. 1, (1753) I, 69; *Poa Japonica* Thunb., Fl. Jap. (1784) 31; *Er. Japonica* (Thunb.) Trin., Mem. Acad.

Petersb. Ser. XI (1831) I, 405. *E. tenella* var. *Japonica* R. & S., l. c. Bentham, l. c., restricts and uses the Linnean specific name as originally applied in the first Ed. of the Sp. Pl., that is, to designate the plant more generally known as *E. Japonica*.

Festuca elatior Linn. Meadow Fescue. A tall, coarse grass, with a large, compound panicle and spikelets about 6 lines long. Rich meadows Keweenaw Co., No. 835, August 30, 1890; Detroit, No. 835a, June 13, 1895; Monroe, No. 5812, June 2, 1921.

Festuca elatior var. *pratensis* (Huds.) A. Gray. Lower (1-3 feet) and more slender with a smaller and simple panicle and smaller, narrower spikelets. Meadows and pastures. Keweenaw Co. No. 594, September 5, 1887; Detroit, No. 594a, June 1, 1894; Rochester, No. 6955, July 9, 1924; Parkedale, No. 3475-½, June 15, 1913; Algonac, No. 3058, August 11, 1912.

Festuca nutans, Spreng. Nodding Fescue. The nodding panicle consists of a number of long, slender branches at first appressed but later spreading and often reflexed. In thin woods and around old stumps in recent clearings, usually near water. Detroit, No. 1374, June 20, 1893; Rochester, No. 1374a, July 4, 1896; Parkedale, No. 3051, August 4, 1912, and No. 3450, June 15, 1913; Amy, No. 6975, July 16, 1924.

Festuca octoflora Walt. Slender Fesccue. In sandy or sterile soils. This is an annual plant, the other species here mentioned being perennials. Orion, No. 980, May 30, 1895; Rochester, No. 980a, June 16, 1909; Marl Lake, No. 4934, June 9, 1918; Erie, No. 7000, July 30, 1924.

Festuca ovina Linn. Sheep'sFescue. Indigenous but also naturalized. In grassy fields and waste places. Very variable and has many varieties. This is a bunch grass without rhizomes. Leaves usually short and involute, not over 0:25 of a line thick. Awns shorter than the coriaceous lemmas. Keweenaw Co., No. 793, August 18, 1890; Detroit, No. 2020-½, June 6, 1907; Ypsilanti, No. 5747, May 15, 1921.

Festuca ovina var. *duriuscula* (Linn) Koch. Leaves usually flat, 0.25 to 0.50 of a line wide. Previously reported as *F. ovina* var. *duriuscula* f. *villosa*, but clearly not that. Rochester, No. 1722, July 4, 1901.

Festuca ovina var. *polyphylla* Vasey. (*F. rubra* var. *heterophylla* of the Michigan Flora, *F. occidentalis* Hook.) In this variety, the plant is more slender and the awns are longer than the membranous lemmas. Rocky woods and bluffs on the Keweenaw Peninsula. No. 531, August 15, 1887.

Festuca rubra Linn. Red Fescue. This is not a bunch grass. The base of the stem is decumbent, and there is a short rhizome or root-stock. Collected and distributed as *F. ovina* var. *duriuscula* but readily differentiated from that by its rootstock. Rochester, No. 4504, June 28, 1917.

Festuca rubra var. *pascua* Anders. A dwarf or stunted variation with a short, thick panicle. Collected and distributed as *F. ovina* var. *alpestris* Anders. Detroit, No. 793a, June 24, 1902 and No. 4509, July 6, 1917.

Festuca rubra var. *subvillosa* M. & K. In this variety the lemmas are conspicuously pubescent. Collected and distributed as *F. ovina* var. *villosa* Schrad. Algonac, No. 3641, May 24, 1914; Ypsilanti, No. 5746, May 19, 1921.

Agropyron repens (L.) Beauv. var. *subulatum* (Schreb.) Reichb. [var. *aristatum* (Doell), Volkart]. Previously reported as var. *agreste* Anders.

Agropyron repens var. *Leersianum* (Wulf. & Schreb.) Reichb. Previously reported as var. *nemorale*, Anders. The plants reported as varieties *agreste* and *nemorale* agree in all respects with the descriptions and plates of Reichenbach's varieties respectively.

Agropyron repens var. *litoreum* (Schum.) Hegi. *Agropyrum litorale* Reichb. Previously reported as variety *littoreum* Anders. but that name as used by Scribner and Smith represents *A. pungens*, a pecies not found in Michigan.

Agropyrum tenerum Vasey, var. *Novae-Angliae* (Scrib. & Sm.) Farwell. Collected at Copper Harbor in rocky woodlands. No. 1614b, August 23, 1898.

Elymus Macounii, Vasey. Woods in Keweenaw Co. No. 710, August 20, 1889. Previously reported as *E. glaucus* Buckl. (*E. Sibiricus* A. Gr. and var. *Americanus* Wats. & Coult.)

Elymus Virginicus Linn., var. *intermedius* (Vasey) Bush. *E. hirsutiglunis* Scribn. The differences in pubescence alone can scarcely give it the status of a distinct species.

Elymus striatus Willd., Sp. Ed. 4 (1897) I 470 and in Enum. Hort. Berol. (1809) 131,132; *E. Arkansanum* Scribn. & Ball, Bull, Div. Agrost. (1901) 24 p. 45 f. 19. Willdenow described the same species as Scribner & Ball, that is, the plant with glabrous or scabrous leaves, sheaths and glumes. I have found this but once in Michigan, at La Salle. No. 7165, September 17, 1924.

Elymus striatus var. *villosus* (Willd.) A. Gr. *E. villosus* Willd., Enum., l. c. Glumes, leaves, and sheaths more or less villous. Generally distributed throughout southern Michigan. Rochester, No. 5010, June 30, 1918.

ELYMUS CANADENSIS, LINN

and

ELYMUS PHILADELPHICUS, JUSLENIUS

Elymus Canadensis Linn is based on descriptions of Chenon and of Morison, as per the Species Plantarum Ed. 1 (1735)) I 83. Following my recommendations on p. 36, Vol. 10, of this journal, the Morison citation becomes the type of the species. *E. Philadelphicus* Juslenius is based on plants from Pennsylvania collected by Kalm according to the author, Cent. I Plant. (1755) and Amoen. Acad. (1759) IV 266. Since *E. Canadensis,* as commonly understood, is not found in Pennsylvania, it stands to reason that the two binomials cannot represent the same species notwithstanding Hitch-

cock's efforts (Cont. U. S. Nat. Herb. [1908] XII 123,124) to show that they are synonymous. Wiegand (Rhodora [1918] XX 87-89) follows Hitchcock and limits *E. Canadensis* to Canada, New England and northern and central New York yet paradoxically unites with it the Pennsylvanian *E. glaucifolius* Muhl. where *E. Canadensis* is not found. Bush (Amer. Mid. Nat. [1926] X, 49, 50, 76, 88) protests against the union of the two species by Hitchcock, Wiegand and others and maintains *E. glaucifolius* as a distinct species to include *E. robustus, E. brachstachys* and *E. crescendus.* It seems that Bush comes closer to being correct than the others but he should have used the earliest name for the species, *E. Philadelphicus* Juslenius, Cent. I Plant. (1755) and in Amoen. Acad. (1759) IV 266. Wiegand, l. c. 89, says "In his description Linnaeus states that the leaves were very broad and the spikelets six-flowered." I fail to find any reference to the width of the leaves in either edition of the Sp. Pl. or in the Amoen. Acad. The only reference to leaves is to color and not to width, and this of *E. Canadensis* in the 2nd ed. of the Sp. Pl.—"Folio hujus rore caerulescente, proesertim subtus abducta, quod non in pracedente" (*E. Sibirics*). This explodes the idea that the plant with conspicuously glaucous leaves is *E. Canadensis.* In *E. Canadensis* the color is dark bluish, like the color of water, while in *E. Sibirica* they are green. Juslenius describes and contrasts his *E. Philadelphicus* with *E. Canadensis* as follows: Elymus (*Philadelphicus*) spica pendula, spiculis sexfloris: inferioribus ternatis, superioribus binatis. Habitat in Pennsylvania. Kalm. *Descr.* Habitus & tota structura simillima *E. Canadensis,* sed *Spica* in hac omino apice nutat ultra basin; at in illa spica parum obliqua persistit. *Spiculae* in hac sexflorae, in illa quadriflorae, sed inprimis spiculae, & pracipue intermedia, in hac latus planum, uti *triticum*, culmo obvertit. In illa & reliquis latus angulatum scapo obvertit. Haec aristas minus rectas, & parum flexuosas, etjam dum floret, ill vero rectas habet; haec spices magis villosas, quam illa gerit. Spiculae sunt patulae, villosae, aristatae. Calyx spicula dimidio brevior.

From the above it will be seen that there is no reference to the leaves at all; that the spikes are pendulous, spikelets

6-flowered and villous, awns bent & flexuous. All these characters are characteristic also of *E. glaucifolius* which came from the same region, Pennsylvania. It is self-evident, therefore, that *E. Philadelphicus* Juslenius & *E. glaucifolius* Muhl. are one and the same. It is also seen that *E. Canadensis* has an erect spike or nearly so, 4-flowered spikelets, *awns erect* (*the Morison plant**) and florets less villous than in the other; these characters, together with the dark bluish color of the leaves, as afore mentioned, point quite strongly and unerringly to the plant recently described by Wiegand, l. c. 84-86, as *E. riparius*. It is more than likely that *E. riparius* is the true *E. Canadensis* as revised, and as it appeared in the Sp. Pl. Ed. 2, (1762) I 123. If so, this would leave the plant that commonly passes as *E. Canadensis* without a name, in so far as I am aware; that is, the plant with conspicuously glaucous leaves villous, according to Wiegand, on the upper surface.

E. Caandensis as it appeared in the Sp. Pl. 1753, is as follows:

ELYMUS spica flaccido-pendula, spiculis inferioribus ternatis; superioribus binatis. Gen. Nov. 1094.

Graman secalinum majus altissimum virginianum. Moris. Hist. 3 p. 180, s. 8. t. 10. f. 2. [should be,—t. 2. f. 5.]. Raj. suppl. 599. *Habitat* in Canada. *Kalm* . . . Variat haec spicis incurvis & pendulis. . . .

There is no specific description original with the Sp. Pl. No reference to the leaves whatever. The spikes are variable, from slightly curved to pendulous, thus including more than one species as these are at present understood. This species, two years later, was revised and divided by Juslenius, un-

* I wish to thank Dr. J. A. Nieuwland for his courtesy and help in looking up the Morison citation for me, which he finds is not as Linn cited it; but should be—Moris. Hist. 3, p. 180, s. 8. t. 2. f. 5. He informs me that the awns of the spike are practically straight, not appreciably curved. This indicates that Linn and Juslenius accepted the Morison citation as the type of *E. Canadensis* Linn. which undoubtedly is *E. riparius* Wieg.

doubtedly with the approval of Linn, who accepted the species as revised for the 2nd. Ed. of the Sp. Pl. This early revision definitely characterizes both *E. Philadelphicus* and *E. Canadiensis*, settles the status of each, and cannot now be disturbed. The *E. Canadensis* of Wiegand, excluding *E. glaucifolius*, probably is but a villous leaved form of *E. Philadelphicus* found in its northern range as *E. robustus* is usually but a green leaved form found in its western range. As to the latter, Wiegand, l. c. 89, unites *E. robustus* and *E. brachystachys* under the former name and says: "The type material of *E. robustus* (*Pammel* Iowa). . . has the lemmas entirely glabrous." I can not and do not agree with Wiegand on two accounts: (1) because the authors described the lemmas as scabrous or pubescent and (2) because they mentioned neither collectors nor collections. How anyone can designate as the type of a species a plant not mentioned by the authors and with a character positively excluding it is beyond my comprehension. If a single specimen is subsequently to be designated as a "type" it at least should be one that agrees with the original description.

The species would be as follows:

Elymus Canadensis Linn, Sp. Pl. Ed. 1 (1753) I 83 as to the Morison plant and as amended by Juslenius in syn. in Cent. I. Plant (1755) and in Amoen. Acad. (1759) IV 266; L. J. Chenon in Gen. Nov. in Amoen, Acad. (1756) III 20; Linn. Sp. Pl. ed. 2 (1762) I 123; Torrey Fl. U. S. (1824) I 137; *E. riparius* Wieg., l. c. 84, 85.

Awns straight, leaves green. Has not been observed in Michigan.

Elymus Philadelphicus Juslenius, ll. cc.; *E. glaucifolius* Muhl. ex. Wild., Hort. Berol. (1809) 131. *E. Canadensis* var. *glaucifolius* (Muhl.) Torr., Fl. U. S. (1824) I 137. Spikes long (8-12 inches) and flexuous, awns curved outward, leaves broad and flat, conspicuously glauceous, rough (not villous) especially above, often smooth beneath toward the base. Detroit, No. 1556, September 17, 1896; Rochester, No. 1556a, September 6, 1909. In the herbarium of Parke, Davis & Co.,

there is a sheet of this collected in August, 1879, by Dr. H. H. Rusby at Delaware Water Gap, Pennsylvania.

E. Philadelphicus var. *hirsutus*, N. Var. *E. Canadensis* Linn ex Wieg., l. c. 87 in large part (exclude syn.) Upper surface of leaves villous. Not observed in Michigan.

E. Philadelpicus var. *pendulus* (Eaton & Wright) N. Comb. *E. Canadensis* var. *pendulus* Eaton & Wright, N. Amer. Bot. Ed. 8 (1840) 232; *E. Canadensis* f. *crescendus* Ramaley, Minn. Bot. Studies (1894) I, 114. Evidently only a green (non-glaucous) phase of the typical form of the species. Detroit (Redford), No. 4753b, October 14, 1917 and No. 7249, October 8, 1924; Ann Arbor, No. 7042a, August 20, 1924. In the herbarium of Parke, Davis & Co. are two sheets of this. One from Franklin, N. J., where collected by Dr. H. H. Rusby in 1878. One from New York without locality, collected in 1881 by O. E. Pearce.

E. Philadelphicus var. *robustus* (Scribn. & Sm.) N. Comb. *E. Canadensis* var. *robustus* (Scribn. & Sm.) MacKenzie & Bush, Man. Fl. Jackson Co., Mo., (1902) 38; Farwell, Ann. Rpt. Mich. Acad. Sci. (1920) XXI 357; *E. robustus* var. *vestitus* Wieg., l. c. 90; *E. glaucefolius crescendus* (Ramaley) Bush, Amer. Mid. Nat. (1926) X 83; *E. robustus* Scribn. & Sm., Bull. Div. Agrost. (1897) 4 p. 37. The leaves usually are green and more or less involute, spikes short, thick, erect, short exserted or more or less included, lemmas, scabrous or pubescent. Marquette*, No. 1619-½, Aug. 30, 1898; Detroit, No. 1409, July 8, 1899; Rochester*, No. 1619b, September 6, 1909. Monroe Piers*, No. 2184-½, August 20, 1910; Oxford, No. 6678, August 8, 1923; Imlay City, Nos. 6685 and 6686, August 15, 1923; Geddes, No. 7057, August 20, 1924; Monroe Piers, No. 7066, August 27, 1924; Squirrel Island, Ontario, Canada, No. 7117, September 3, 1924.

E. Philadelphicus var. *brachystachys* (Scribn. & Ball) N. Comb. *E. brachystachys*, Scribn. & Ball, Bull, Div. Agrost.

* Early determination; specimens not at present available for re-examinations which might place them in other categories.

(1901) 24 p. 47. E. *Canadensis* var. *brachystachys* (Scribn. & Ball) Farwell, Ann. Rpt. Mich. Acad. Sci. (1920) XXI 357. *E. robustus* Scribn. & Sm. in Wieg., l. c. 89; *E. glaucifolius robustus* (Scribn. & Sm.) Bush., l. c. 86, 87. Similar to var. *robustus* but the lemmas are glabrous or rarely, sparsely and minutely strigillose. Detroit, No. 1409, August 11, 1893; Orion*, No. 1409a, August 29, 1895; Island Lake*, No. 1929-½, July 16, 1905; Rochester*, No. 2109-½, August 15, 1909; Ann Arbor, No. 7042, August 20, 1924; Denton, No. 7131, September 10, 1924; Dearborn, No. 7508, August 5, 1925.

Asperella Hystrix (Linn) Humb. var. *Bigeloviana* Fernald. Porcupine Grass. In the herbarium of Parke, Davis & Co., is a sheet of this variety collected at East Greenwich, N. Y., in 1867, by Dr. Asa Fitch.

Koeleria cristata (Linn) Pers. This grass is found in dry, usually sandy soil. Bloomfield, No. 4609, September 16, 1817; Ypsilanti, No. 5240, June 15, 1919; Algonac, No. 7421, June 17, 1925.

Reboulea obtusata (Mx.) A. Gr. var. *lobata* (Trin.) Farwell. The panicle is much contracted, spike-like and lobed. In gravelly soil Copper Harbor, No. 7748-½, August 5, 1926; Lake Linden, No. 7761-½, August 8, 1926.

Eleusine Indica Gaertn. Yard Grass. Waste places and in old yards. Monroe, No. 6721, August 22, 1923; Detroit, No. 7635a, September 10, 1925.

Anthoxanthum odoratum Linn. Sweet Vernal Grass. Usually in meadows and pastures. Detroit, No. 5033m, July 6, 1918; Ypsilanti, No. 5858, June 12, 1921; Clifton, No. 7770-½, August 11, 1926.

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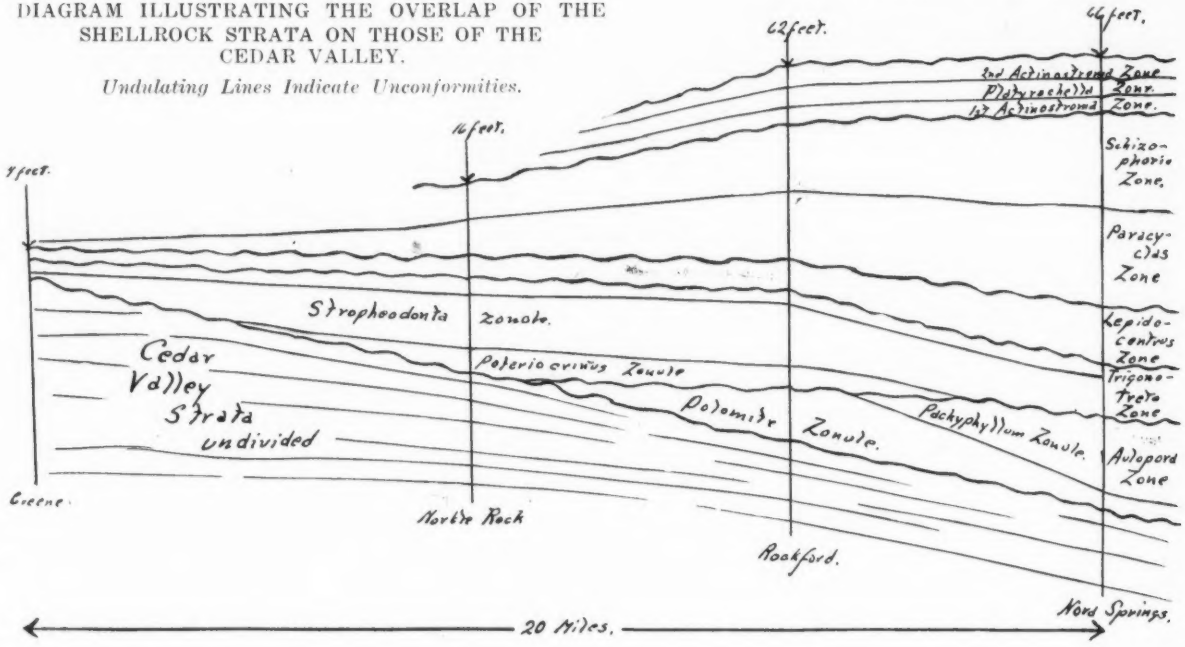
* Early determination; specimens not at present available for re-examinations which might place them in other categories.

Department of Botany,
Parke, Davis N *Co.,*
Detroit, Michigan.

(Belanski on Shellrock Stage)

DIAGRAM ILLUSTRATING THE OVERLAP OF THE SHELLROCK STRATA ON THOSE OF THE CEDAR VALLEY.

Undulating Lines Indicate Unconformities.



THE SHELLROCK STAGE OF THE DEVONIAN OF IOWA

By C. H. BELANSKI

I. INTRODUCTION

A—NATURE OF THE STUDY

During the past ten years the author has done considerable collecting in Devonian strata of Floyd and Cerro Gordo counties in the north-central part of Iowa. Strata of various ages are exposed in these two counties, virtually all of which belong to the Upper Devonian. It was early noted that the fossils collected from these strata, then referred to the Cedar Valley Stage, were widely different from fossils found in that stage at Waverly, Waterloo, Iowa City and other points farther south where the typical Cedar Valley beds are exposed. Furthermore, attempts to correlate the sections of those beds, as published by various authors, with the exposures in Floyd and Cerro Gordo counties were far from satisfactory. As a result of these discrepancies work was started in 1920 to find the true relationships of these northern strata to those exposed in the central and southern portions of the Iowa Devonian belt.

Every available outcrop in the region described has been sectioned and the fossils obtained have been carefully separated and catalogued according to the members and localities from which they came. During the progress of this work over 100 sections have been made and upward of 30,000 fossils collected. Detailed maps and tabular section charts have been made of all of the territory surveyed, which includes the western half of Floyd County, the eastern portion of Cerro Gordo and the northern portion of Butler County. Work has been carried southward and eastward to the points where the beds under discussion are no longer exposed, and although the study is by no means complete, it has reached a point where publication of the conclusions and pertinent

data is not only justified, but should prove of value to paleontologists and stratigraphers.

Although this is but a preliminary paper it nevertheless describes the beds fully enough that their relationships can be understood and possibilities of later confusion avoided. Unfortunately, though some work has been done along Lime Creek west of the Floyd County line, the exact relationships of the zones and zonules in the lower part of the sections in the Portland and Mason City districts have not been fully determined. The substages can be traced more or less continuously throughout this area, but the beds exhibit such sharp and rapid lithologic changes that it is unwise to delineate the minor members until further field work determines their relationships to each other and to the eastern sections.

The territory yet to be studied consists of the northern portion of Cerro Gordo County and a portion of southern Worth County. Perhaps the strata under consideration also are exposed in the south-western corner of Mitchell County. The beds of the Shellrock stage exposed along Lime Creek and its tributaries will form the second, and probably the final report on the stratigraphy of the Shellrock stage, for which it is hoped the field work will be completed by the end of 1927.

B—PREVIOUS GEOLOGICAL WORK

Previous detailed geological work done in the present area has been slight. Owen[1] makes reference to the "beds of the Shellrock Valley." Hall[2] devotes a chapter to the geology of Howard, Mitchell, Chickasaw, and Floyd counties in which some of the beds of the present area are described and correlated with divisions of the New York Devonian. Hall and Whitfield's paper[3] again makes reference to the beds of this stage and a section from an exposure near Rockford is given, but the strata are again referred to the Chemung. McGee

1 Rept. of Geol. Wis. Minn. pt. I, p. 78; 1852.
2 Geol. of Iowa. Pt. I; 1858.
3 23rd Ann. Rept. N. Y. State Cab.; 1872.

gives a short description[4] of the beds of the Mason City district. Calvin[5] devotes 16 pages to the description of the "Cedar Valley" rocks of Cerro Gordo County and also gives a general section of the beds exposed at Nora Springs. He places all of these strata in one substage, and on the basis of the heavy stromatoporoidal beds shown at Mason City and Nora Springs correlates these limestones with similar ones in the Cedar Valley stage of Johnson and Black Hawk counties. To the strata shown in Floyd and Cerro Gordo counties he applies the term Mason City substage. Arey[6] in his report of Butler county mentions exposures of "Cedar Valley" strata along Coldwater Creek southwest of Greene, but does not note the occurrence of the Shellrock strata at these points.

In 1913[7] Thomas named the Nora Limestone from strata exposed in western Floyd County but published no definition. Fenton[8] refers to the "Nora Formation" and in the same map uses the name "Shellrock"as a geologic unit, making it a substage of the Cedar Valley stage but giving no sections or definitions. In 1924 the same author[9] again refers to these strata in a similar manner. Thomas[10] first used the name Shellrock in the sense of a stage name, including his Nora Limestone and the Mason City substage of Calvin as substages, and suggesting other additional ones. Here again no sections were given nor definitions made.

C—SHELLROCK STAGE

In northern Butler, western Floyd, northeastern Cerro Gordo, and southern Worth counties there is developed a group of strata consisting largely of shaly limestones and dolomites with occasional shale layers and more or less lithographic limestones. These beds form a narrow belt extend-

4 Rept. 10th Census, Vol. X,, pp. 261-263.

5 Iowa Geol. Surv. Vol. 7; 1897.

6 Iowa Geol. Surv. Vol 20, pp. 30-31; 1910.

7 Science n. s. Vol. 37, p. 459; 1913.

8. Am. Jour. Sci. 4th ser., Vol. 48, pp. 357-358; 1919.

9 Cont. Mus. Geol. Univ. Mich. Vol. 1, map explanation, frontispiece; 1924.

10 Iowa Geol. Surv. Vol. 29, pp. 411-412; 1924.

ing along the Shellrock River and its tributary streams and never exceeding twenty miles in east-west width. They lie above the beds of the Cedar Valley stage and below the blue shales of the Juniper Hill Shale[11], being separated from both of these formations by sharp, persistent, unconformities. These beds are held to constitute a new and heretofore undescribed stage of the upper Devonian of Iowa, and because of their development along the Shellrock River, the name *Shellrock Stage* is here proposed for them. They attain their greatest thickness along that stream between Nora Springs and Rockford, two towns near the western border of Floyd County. Exposures of the various substages of the Shellrock are more or less continuously shown along the Shellrock from Greene, in northern Butler County, to Manly, in southeastern Worth County. Along Lime Creek these same beds are exposed from Rockford, at the mouth of that stream, to Fertile in southern Worth County. Still other exposures lie along Willow creek in Mason City, along Flood creek from Rudd southward, and along the Coldwater creek south and west of Greene. This paper deals only with those strata shown along the Shellrock river and Flood creek in Floyd, Butler and eastern Cerro Gordo Counties, an area some 30 miles in length and 12 in width.

The Shellrock beds of this area apparently were deposited close to the eastern and southern margins of the sea, as is indicated by their rapid thinning to the south and east; while the numerous unconformities and erosion planes show that during the period of deposition there was much disturbance of the sea basin. In the western areas, however, the erosional periods were much less marked and the beds themselves are more stable in character.

The lithological character of the different units or zones of this stage, in the area discussed, is extremely variable. No one zone holds its thickness for any great distance and some of the faunules present in one zone at one locality may be absent or replaced by different faunules at another set of localities where the same zone is exposed. The lithologic and

11 Thomas, Iowa Geol. Surv. Vol 30, footnote p. 116; 1925.

faunal changes of the strata are further complicated by the amount of erosion which some of the beds have undergone, five distinct unconformities being shown in Floyd County alone.

Northward and westward all of the beds of the Shellrock stage become markedly dolomitic, forming part of a broad belt running roughly east and west along the northern border of Iowa in which all of the Devonian strata become more or less dolomitized. This belt is first noted at Cresco, in Howard County, whence it extends westward into Mitchell and northern Chickasaw counties, across northern Floyd and finally ends in western Cerro Gordo County.

D—TERMINOLOGY

The term *zone*, as here used refers to a particular group of rocks, not necessarily retaining the same lithologic character wherever exposed but marked by a species or group of species which are especially characteristic to them. The term *zonule* refers to a subdivision of a zone lithologically distinct from other zonules of the zone. *Faunule* is held to refer to an association of species forming a more or less distinct biologic group, the term therefore having only biologic significance.

A *zonule* is marked by a *faunule* found only in that zonule. Neither of these necessarily need be found at all points where the horizon is exposed, but may be replaced by a different zonule carrying a different faunule, or they may be entirely absent in the zone.

In the Trigonotreta zone, for example, there are in the Nora Springs phase four members or zonules each bearing its own distinct faunule but all tied together but the abundant occurrence of *Trigonotreta shellrockensis* n. s. One of the members of this zone is the Decadocrinus zonule, a series of thin-bedded magnesian limestones carrying a faunule of crinoids and molluscs. In the Rockford phase this same horizon is occupied by the Stropheodonta zonule, a series of heavy bedded, shaly limestone carrying a faunule of brachiopods, corals and molluscs.

Such rapid lithologic and faunal changes are the rule rather than the exception in Shellrock strata; no great number of the zonules holding their character for more than five miles.

II—STRATIGRAPHY

A—GENERAL

As has been said, the Shellrock stage lies between the upper Cedar Valley limestones and the shales of the Juniper Hill formation. It consists largely of limestones and dolomites with several shale beds which are more or less persistent, and may be divided into three substages, which contain several zones, and a still larger number of zonules.[12]

Because of the marked areal variation of the strata, it has been found necessary to describe the Shellrock stage according to its local aspects or phases. These, however, are complicated, and become intelligible only when compared with a generalized standard section; which also becomes necessary for reference in future descriptions of fossils. The discussion of stratigraphy therefore begins with the general section, which progresses from top to bottom of the beds described. In the section the capitalized letters indicate substages while Roman numerals are used to indicate zones. Arabic numerals indicate the zonule horizon while the letter

12 In the present paper zones and zonules are designated only by the generic name of the most diagnostic fossil. In the final paper these beds will be designated by the specific name as well; thus the Camarophoria zonule of the present paper will become the Camarophoria paupera zonule etc. Because of the large number of new species it is impossible at present to give full name for these beds. Furthermore it will very likely be necessary to change certain of the names, particularly those of the Nora substage. As will be noted the bulk of the fauna of this substage is stromatoporoidal and since virtually nothing is now known of the specific relations of these fossils, such changes must be deferred until these fossils are described. This also holds true for the terms 1st. and 2nd. Actinostroma zones as used in the present paper. The number of zonules, particularly in the Nora substage, will be materially increased by further field work. Thus it is known that the upper Actinostroma zone, which in this paper appears to hold but one basic member, consists of three members in the undescribed western phases.—C. H. B.

immediately following the numeral indicates the particular zonule in that horizon. Thus it will be seen that there are sometimes several distinct zonules present at the same horizon but at different points.

C.—THE NORA SUBSTAGE

Hard, white, stromatoporoidal limestone, magnesian shale, shaly limestone, and (in the northern phases) dolomites, varying in thickness from 6 to 20 feet. The substage is best developed near the town of Rockford; it thins rapidly toward its eastern and southern borders, and is present only as remnants from Rudd southward to Marble Rock. At Greene it appears to be absent.

The type exposure of this substage is an abandoned quarry near Nora Junction, in the northeast quarter of the northeast quarter of section 18, T. 96 N., R. XVIII W. It was designated by A. O. Thomas when he named the Nora Limestone[13] but no section was given. In another paper Thomas published a photograph of an exposure near Rockford, though he still refrained from giving a section.[14] The best exposures, as has been said lie near the town of Rockford.

VIII.—SECOND ACTINOSTROMA ZONE

This zone, throughout the area described, is composed largely of shale or argillaceous limestone so crowded with stromatoporoids that it has the appearance of a true limestone. It is typically developed along the Shellrock River from Rockford to Nora Springs, its upper surface being deeply eroded and generally covered by the basal blue shales of the Juniper Hill formation. Its maximum thickness in Floyd County (at Rockford) is 84 inches.

24a—PSEUDOTECTUS ZONULE

This is the typical phase development of the second Actinostroma zone in the central Shellrock region. The predominant fossils are closely crowded colonies of several species of

13 Science, n. s., Vol. 39, p. 459; 1913.

14 Iowa Geol. Surv. Vol. 29, fig. 62, p. 411; 1924.

Actinostroma. Throughout the shale matrix there are abundant brachiopods, and echinoderms, the most common of these being a fine-ribbed *Atrypa*, an undescribed *Pseudotectus*, *Euomphalus planodiscus* ? Hall and several other small gastropods and cephalopods.

24b—STROMATOPORA ZONULE

This is the northward extension of the preceeding member, and is shown along the Shellrock River from Nora Springs northward to Rock Falls. It is more calcareous than the zonule just described and carries a very different fauna. The laminar stromatoporoids are still abundant with the genus *Actinostroma* persisting. With these, and occasionally composing the bulk of the fauna, are numerous laminar colonies of *Stromatopora*. Small fossils are apparently limited to the fine-ribbed *Atrypa* and occasionally a small *Athyris*. The maximum thickness in the Reed Creek phase is 90 inches.

VII.—PLATYRACHELLA ZONE

This member is well developed over all of western Floyd County, where it is normally composed of three subzones. It is a true shale stratum although the central member is more calcareous than the others. In the area described the various members are generally conformable, though in the more western and northern phases there is evidence of erosion between certain of the strata.

23a—UNNAMED ZONULE

This member is well developed over all of western Floyd River from Rockford north to the Floyd-Cerro Gordo County line. It is a magnesian shale, generally barren, but at Rockford contains casts of a undetermined species of *Platyrachella*. At this point it also reaches its maximum thickness, 75 inches. This shale becomes more indurated in the northern phases, in places being represented by firm, brown dolomite.

22a—SYRINGOPORA ZONULE

This zonule is normally composed of shaly, thin-bedded limestone some 18 inches thick, containing thousands of obscure fucoidal markings, together with small crinoid stems,

occasional molluscs and rugose corals, and rare brachiopods. The zonule is typically developed at Rockford, where its upper surface is covered by the tubes of a slender, undescribed species of *Syringopora*. It can be traced up the Shellrock River nearly to the Baumgardner phase, where it feathers out. North of Nora Springs the same stratum reappears as the

22b—PTYCHOPHYLLUM ZONULE

This member differs from the preceding chiefly in the absence of the *Syringopora* and in a much greater abundance of brachiopods. Lithologically it is more shaly and more unstable than its southern equivalent, and shows a tendency to intergrade with the shale stratum below. Northward from the Keidle Bluff phase it is represented by barren dolomite which is separated with difficulty from the beds above and below.

21a—SCHUCHERTELLA ZONULE

This name is used for the shale stratum below the Syringopora zonule at Rockford. Like the unnamed zonule at the top of the zone, it is highly magnesian; yet it carries an abundance of well preserved fossils; brachiopods, corals and echinoderms being common. The most diagnostic species being *Platyrachrella ballardi* n. s. and an undescribed *Schuchertella*. Northward along the Shellrock the member can be traced to the Baumgardner phase, although in this distance it loses its faunule. Because of this, and also because of the lithologic resemblance to the unnamed zonule of this zone, it follows that from the point of disappearance of the Syringopora zonule to the reappearance of the Ptychophyllum zonule, the upper and lower shale members of the Platyrachella zone can not be separated—as is shown by the Nora Springs phase. North of Nora Springs, in the Reed Creek phase, the Schuchertella zonule again becomes fossiliferous, specimens of *Platyrachella ballardi* n. s. found here attaining nearly twice the size of those from Rockford. Other brachiopods appear to be absent, although rugose corals are common. All of the fossils are casts. In the phases north of this, fossils are rare.

VI.—FIRST ACTINOSTROMA ZONE

Unlike the second Actinostroma zone, this is primarily a limestone member, for though its southern phases are composed largely of laminar stromatoporoids, the matrix is a hard gray limestone. Along the Shellrock River in Floyd County it is composed of but one unit, the upper surface of which is considerably eroded. Throughout this area it forms the base of the substage and is separated from the substage below by a distinct unconformity. In the phases shown north of Nora Springs, the basal Expansum zonule is reenforced by two additional, superimposed zonules.

20a—UNNAMED ZONULE

At the point of its appearance, in the Sherman Bluff phase, this zonule is composed of soft, brown, crystalline, barren dolomite, separated from the subjacent beds by a strong bedding plane, which to the westward becomes an unconformity. In the Rock Falls phase this zonule is represented by nearly four feet of hard, blue-gray limestone containing numerous spheroidal stromatoporoids as well as thousands of slender-stemmed idiostromids. The generic or specific relations of the stromatoporoids being unknown, they afford no name for the rocks which contain them.

19a—MACGEEA ZONULE

This member appears as remnants a short distance west of the Floyd County line, increasing northward until in the Rock Falls phase its thickness is over 6 feet. Its fauna is best shown in the Reed Creek phase, where the member is charged with abundant specimens of tabulate and rugose corals, including two or three undescribed forms of *Macgeea*. Other fossils are rare. In the Reed Creek phase the member is a hard, brown limestone which northward becomes a firm, fine-grained, unfossiliferous dolomite scarcely to be distinguished from the beds above and below. In the Rock Falls phase it is sparingly fossiliferous, and like the zonule above, is composed of hard, fine-grained, blue-gray limestone.

18a—EXPANSUM ZONULE

This name is given to the one bed composing the first Actinostroma zone in the central Shellrock region [Rockford

to Nora Springs), where it is composed of hard, blue-gray limestone crowded with colonies of laminar stromatoporoids, the most common of which is *Actinostroma expansum* (H. & W.) With these are several species of *Cyathophyllum* and *Phillipsastrea*. Other fossils are uncommon.

18b—PRISMATOPHYLLUM ZONULE

This name is applied to beds occupying the same horizon as the Expansum zonule but developed in the eastern and southern portions of the Shellrock area. It is best shown along Flood Creek near Rudd, where it is composed of soft, yellow, argillaceous limestone carrying numerous laminar stromatoporoids but characterized mainly by its abundant brachiopods and corals; *Prismatophyllum oweni* n. s. being especially common. Some forty species of corals and brachiopods are known from this zonule, very few of which occur in the Expansum zonule. The same, or a very similar faunule, is found north of Marble Rock and throughout Ulster township.

(In the phases to the north of Nora Springs, the Expansum zonule again changes. This is specially marked in the Reed Creek phase, where the member is composed of hard, brown limestone bearing spheroidal stromatoporoids, the laminar forms being uncommon to rare. A flattened form of *Trigonotreta shellrockensis* n. s. is also common here, along with other brachiopods not found in either of the equivalent zonules to the south and east. Northward, this, like the zonules above, becomes dolomitized and loses its faunule. It suffers a considerable decrease in thickness but can be traced to the Rock Falls phase where it once more becomes a limestone bearing spheroidal stromatroroids. For this facies a new name will later be proposed.)

B—ROCK GROVE SUBSTAGE

Magnesian shale, shaly limestone, and impure dolomite, typically developed at Nora Springs, but present as a whole or in part at all phases found in Floyd and eastern Cerro Gordo counties; thinning rapidly in all directions from Nora Springs. In the Mason City district it apparently is repre-

sented by only the lower (Gomphoceras) zonule of the Paracyclas zone, the superjacent zonules having been eroded away. To the south and east of Nora Springs this erosion plane again becomes more marked, cutting into successively lower and lower beds. Where the substage is typically developed the top of the upper (Schizophoria) zone is separated from the overlying Nora substage by a sharp unconformity, while the base of the substage is set off sharply from the subjacent beds by another, but less marked, erosion plane.

The term Rock Grove is given to this substage because of its great development in Rock Grove township of Floyd County. The type exposure is located on the eastern (left) bank of the Shellrock River a short distance southeast of Nora Springs, in the southwest quarter of the northeast quarter of section 17, T. 96 N., R. XVIII W.

V.—SCHIZOPHORIA ZONE

This zone is well developed throughout the western portion of Floyd County, north of Rockford. It normally is composed of earthy dolomites and magnesian and calcareous shales with some shaly limestones, attaining its maximum thickness (12 feet) at Nora Springs. It is separated from the overlying Nora substage by a strong unconformity which is well shown at various points near Rockford, Nora Springs and Rudd. In the Bjorgason phase, north of Nora Springs, the uppermost member of the zone is eroded away and in less than a mile to the north of this, the shaly beds below, here comprising the balance of the zone, also disappear.

17a—STROBILOCYSTITES ZONULE

This name is given to a soft, argillaceous limestone developed below the Nora substage on the eastern side of the Shellrock River, southeast of Rockford, and noted only in the Rockford phase. It apparently has no direct time equivalent in any of the other members of this zone. The maximum thickness is 18 inches. It is very fossiliferous, the most common form being a species of *Strobilocystites* closely allied to *S. calvini* White, with which are associated many other echinoderms and several brachiopods. Its closest faunal

relationships are with the Camaraphoria faunule, at the top of the Mason City substage. The absence of the Strobilocystites zonule at other points north and east of Rockford apparently is due to erosion.

16a—ULSTERENSIS ZONULE

This is a group of heavy-bedded, earthy dolomites, which are well exposed along the Shellrock from Nora Springs to Rockford, normally forming the top of the substage. Their contact with the Nora substage is sharply unconformable. The zonule attains its maximum thickness (72 inches) at Nora Springs. At Rudd, the upper, more fossiliferous portion is eroded away and the member is less than 20 inches thick, while it apparently is absent at Marble Rock. Fossils are abundant, but they consist entirely of casts, which, however, are well preserved. The most common form is *Spirifer ulsterensis* n. sp., which includes more than half of the total number of specimens found. *Schizophoria floydensis* n. sp. is also common as well as several other brachiopods. Corals and echinoderms are rare.

16b—CONULARIA ZONULE

This name is applied to beds equivalent to the Ulsterensis zonule and of much the same lithologic character, developed along the Shellrock River north of Nora Springs. The bedding is thinner and the member itself thins to the northward, finally disappearing in the Bjorgason phase. The abundant brachiopods of the Ulsterensis faunule are replaced by numerous molluscs and fish, with an undetermined *Conularia* the diagnostic fossil.

15a—ATRYPA ZONULE

Magnesian shales which underlie the Conularia and Ulsterensis zonules, in places intergrading with the latter, though not with the Conularia beds, and attaining a maximum thickness of 90 inches at Nora Springs. The only fossils noted are *Spirifer ulsterensis* n. sp. and a coarse-ribbed *Atrypa*, both of which are found in the Ulsterensis zonule. This zonule has not been noted south of Marble Rock and in

the northern part of the Sherman Bluff phase has been removed by erosion. Although faunally identical with the Ulsterensis faunule, yet the lithologic difference of these two would seem to warrant separation of the two zonules.

14a—LOXONEMA ZONULE

This member is typically developed along Flood creek, near Rudd, where it is composed of 18 inches of soft shaly limestone. It, or an equivalent zonule, is seen again along the stream at Rockford, but apparently is lacking in the Baumgardner and Nora Springs phases and in most localities south of Rockford. The most common fossil is *Schizophoria floydensis* n. s. the valves of which occur in thousands. The *Loxonema* from which the zonule is named is a small form closely resembling *Loxonema pulchra* (F. & F.) from the Owen substage, at the top of the Iowa Devonian. This species, and several other gastropods are very abundant.

14b—CRANIA ZONULE

This occupies the same horizon as the Loxonema zonule but is a much more shaly facies, best developed in the central part of Ulster township with a maximum thickness of 20 inches. Faunally there is a marked difference in the two; the Crania zonule contains very few molluscs but hosts of bryozoans, brachiopods, and echinoderms. The diagnostic fossil is a peculiar *Crania*, the separated valves of which are abundant.

IV.—PARACYCLAS ZONE

This, like the overlying zone, is well developed in western Floyd County. It normally is composed of shaly limestone through its entire thickness. The upper beds apparently are conformable with the Schizophoria zone above, where that member is present; its base is set off from the Mason City substage below by a well marked unconformity, as well as by distinct lithologic and faunal changes. It is the most widespread zone of the substage, being found with practically its entire thickness at all exposures studied.

13a—PRODUCTELLA ZONULE

A series of irregularly bedded, shaly limestone, best developed along Flood creek near Rudd, where they are about 40 inches thick. It is crowded with fucoidal and molluscan casts, while the upper ten inches bear an undetermined species of *Productella*, the shells of which are extremely abundant. This or an equivalent zonule, bearing the molluscs but not the *Productella* is shown along the Shellrock from Rockford to the Baumgardner phase. The zonule is apparently not developed in the vicinity of Nora Springs.

12a—PTERINEA ZONULE

This zonule consists of a series of firm to hard, shaly, semimagnesian limestones and buff colored dolomites typically developed at Nora Springs with a thickness of 45 inches. It appears more or less continuously from Greene to Sherman Bluff, where it merges with the zonule below. Wherever shown it is nearly barren, a single cast of *Pterinea* having been found in the Nora Springs phase and other poorly preserved molluscs near Greene.

11—GOMPHOCERAS ZONULE

A series of thin-bedded shaly limestones with regular shale partings which form what perhaps is the most widespread and stable member of the substage, extending from Greene northward to the Bjorgason phase with practically no lithologic or faunal change. Northward from the Bjorgason phase it merges with the Pterinea zonule and, in common with the other strata of these phases, becomes heavily dolomitized. Its thickness increases to nearly 10 feet and the beds become much heavier. In the Mason City sections the Gomphoceras zonule is the only member of the Rock Grove substage, being represented by from 10 to 12 feet of hard, blue-gray, sublithographic limestone. In Floyd County the faunule of this unit is largely molluscan, consisting of several species of pelecypods, a large, rapidly expanding form of *Gomphoceras*, beside fish and crustacean (?) remains. At Nora Springs it has a thickness of 54 inches, the greatest shown in Floyd County.

A—MASON CITY SUBSTAGE

Shaly, blue-gray limestone, impure dolomites, occasional layers of shale, and some lithographic limestones; typically developed at Mason City, where virtually all of the substage consists of heavy-bedded dolomite. The zones and zonules, however, are best shown in western Floyd County, where the dolomitization is less marked and fossils better preserved. Southward and eastward from Mason City the substage thins rapidly, though it is represented in all of the phases in western Floyd County. Its upper surface is undulating, and generally marked by iron-filled cavities, the unconformity being most marked in the northern phases. The basal beds are separated from the subjacent Cedar Valley stage by an unconformity which is most strongly marked in the southern phases, in which a strong overlap of the upper zones is shown, thus recording the progressive encroachment of the early Shellrock sea. At Marble Rock and Greene the Stereocrinus and Stropheodonta zonules of the Trigonotreta zone form the base of the substage, while from Rockford northward the Dolomite zonule of the Aulopora zone forms the base. The type exposure of this substage lies in the western part of Nora Springs along the eastern (left) bank of the Shellrock River in the southeast quarter of section 7, T. 96 N., R. XVIII W.

The term Mason City substage was originally used by Calvin[15] and was applied by him to all of the "Cedar Valley" beds shown in Cerro Gordo and western Floyd counties beneath his "Lime Creek Shale." Later this name was amended to Mason City dolomite[16] a modification which may well be abandoned, since a great part of the substage is not dolomite.

Unfortunately, the stromatoporoidal beds of Calvin's Mason City sections, which he thought were identical with beds exposed near water level along the Shellrock west of Nora Springs, really belong to the lower part of Thomas' "Nora Limestone," and form the First Actinostroma zone of this paper; while the calcilutites and heavy-bedded limestones be-

15 Iowa Geol. Surv. Vol. 7, p. 144; 1897.
16 Iowa Geol. Surv. Vol. 29, p. 412; 1924.

neath the stromatoporoid beds at Mason City are equivalent to the lower part of the Paracyclas zone, which in turn forms a part of the Rock Grove substage as here defined. This leaves only the lower, heavily dolomitized beds of the Mason City section to which the term Mason City substage can now be applied. No type exposure was indicated by Calvin or Thomas; it is here located at Nora Springs because the zones there are more distinct and their faunas more readily determined than at Mason City. With the exception of one thin layer of shale at "Parker's Mill" in Mason City [17] the beds of this substage there have proved to be barren.

III.—LEPIDOCENTRUS ZONE

The Lepidocentrus zone is typically developed along the Shellrock River at Nora Springs, where it is composed of impure limestone the texture of which varies considerably. It forms the uppermost zone of the Mason City substage throughout all of western Floyd County and its upper surface always bears evidence of a considerable erosion break shortly following its deposition.

10a—CAMAROPHORIA ZONULE

This zonule is typical developed at Nora Springs, where it is composed of some 18 inches of soft, yellow-brown, argillaceous limestone. It extends southward some two miles, gradually changing its character until at the Rock Grove Mill it is represented by the Cladopora zonule [10b]. The Camaraphoria zonule reappears at Rockford, to again be replaced by the Cladopora zonule from Marble Rock to Greene. Southwest of Greene, in section 1 of Benezette township, it again appears along the southern slopes of Coldwater creek. Northward from Nora Springs the strata retain the Camarophoria faunule, but in common with the other beds of these phases becomes heavily dolomitized and, from the Reed Creek phase northward, hardly can be separated from sub- and superjacent strata.

17 The mill is now gone but the name remains. The locality lies on eastern (right) bank of Willow creek just south of the State Street bridge.

The Camarophoria faunule is very rich, containing not less than 100 species. The most common forms are *Camarophoria paupera* n. sp., *Lepidocentrus thomasi* n. sp. *Strobilocystites schucherti* Thomas, *Stropheodonta cicatricosa* n. sp., *Cyathophyllum floydensis* n. sp., *Phillipsastrea minutissima* (Webster) and *Hypothyridina magister* n. sp. The echinoid material is exceptionally interesting.

10b—CLADOPORA ZONULE

This name is given to beds equivalent to the Camarophoria zonule but which are more calcareous and which are shown in the southern and eastern phases. The zonule first becomes marked in character at the Rock Grove Mill and continues southward nearly to Rockford, where the Camarophoria zonule is again shown. South of Rockford the Cladopora zonule reappears, continuing with but little change southward to the exposures in section 14, Coldwater township, southwest of Greene. The same, or closely related zonule is found along Flood creek from Rudd to Roseville. The average thickness of this member is 12 inches, thinning to 9 inches at Greene. Its faunule is rich in specimens but poor in species; an undetermined species of *Cladopora* being common as well as large forms of "Atrypa reticularis."

9a—ATHYRIS ZONULE

A series of hard, blue gray to buff, somewhat shaly limestones which lie below the Camarophoria zonule at Nora Springs. The zonule extends southward about a mile from that point, where it feathers out. It is well developed north of Nora Springs where, like the Camarophoria zonule, it becomes dolomitized and almost unrecognisable. It contains abundant laminar and hemispherical stromatoporoids belonging largely to the genus *Actinostroma*. With these are associated several species of brachiopods most of which occur also in the Camarophoria zonule; their numbers are small, however, when compared with those of the Camarophoria zonule. The greatest thickness of this member is 32 inches, at Nora Springs.

8a—EATONIA ZONULE

Soft, yellow, shaly limestone and calcareous shale, absent at Nora Springs and other northern phases. Its most northward occurrence is at the Rock Grove Mill where it has a thickness of 6 inches. This thickness increases to the southward, reaching 27 inches some three miles southeast of the Rock Grove Mill. At Rockford the member is represented by about the same thickness of firm blue gray limestone which character is held to Marble Rock. At Greene it is again represented by shale and shaly limestone some 18 inches thick. The member, wherever found, carries a rich and diversified faunule, some 90 species being known. *Hexacrinus springeri* Thomas is very common and also *H. iowensis* Thomas. In the Baumgardner phase *Eatonia gregaria* n. s. and *Devonocidaris phimaevus* n. sp. are also common.

This member occupies the same horizon as the Athyris zonule but cannot be said to be a continuation of that bed since the Athyris zonule feathers out some three miles north of the appearance of the Eatonia beds. Its base is sharply set off from the Cyrtoceras zonule by a strong persistent unconformity.

II.—TRIGONOTRETA ZONE

This zone is normally composed of hard blue limestone, shaly limestone and at the base shale or magnesian limestone. It is well shown throughout western Floyd County, being present, at least in part, in every phase from Nora Springs southward to Greene. Wherever shown in Floyd County, its upper surface bears an unconformity which apparently marks a considerable period of erosion. Though the zonules and faunules of this zone vary considerably, the character of the whole remains fairly constant.

7a—CYRTOCERAS ZONULE

A series of hard, fine-grained limestones which are well developed along the Shellrock River from Nora Springs southward. The upper surface of this member shows considerable erosion, particularly in the vicinity of Nora Springs. Throughout western Floyd County the zonule is highly fossiliferous, the most abundant fossil being *Trigonotreta shell-*

rockensis n. sp. Numerous large cephalopods occur: three species of *Cyrtoceras*, three of *Orthoceras*, and a doubtful *Centroceras*. Other molluscs are common, as well as poorly preserved crinoids. The maximum thickness of this zonule, 35 inches, is found in the Baumgardner phase.

6a—SYMBATHOCRINUS ZONULE

This consists of from 4 to 8 inches of soft shaly limestone with thin shale partings, the member at most points being readily separated from the adjacent beds by its shaly nature, though in the Roseville and Marble Rock phases the distinction is wholly biologic. The dominant fossils are crinoids of several species, whose parts nearly always are so scattered that specific relations are uncertain. An undescribed *Symbathocrinus* is common, as well as plates of a doubtful *Poteriocrinus*. In Floyd and Butler counties the member contains abundant fucoidal casts similar to those of the genus *Gracilerectus* Webster.[18] Small brachiopods are common.

5a—STROPHEODONTA ZONULE

A series of firm, drab, shaly or slightly magnesian limestones, typically developed at Rockford where they reach their greatest thickness: 96 inches. There they contain a large Strophеodonta allied to *S. scottensis* n. sp. of this paper, occasional rugose corals, and casts of molluscs. From Rockford to Greene the zonule thins; partly by feathering out, and also by overlap on the Cedar Valley strata with which it is in contact from Greene nearly to Marble Rock. Northward from Rockford it also becomes thinner and slightly more magnesian, and at Nora Springs is represented by the following member.

5b—DECADOCRINUS ZONULE

This, like the preceeding, is composed of irregularly bedded, shaly or magnesian limestones, the later being most marked toward the north. The brachiopod faunule of the southern phases is largely absent here, while throughout the upper portion of the zonule there are thin lenticular layers

18 Am. Mid. Nat., Vol. 16, p. 288;1920.

of encrinital limestone. Some six species, of as many genera, of crinoids are known to occur in these lenses, while on other similar lenses are found an undescribed *Productella*, a very elongate pelecypod and dissociated echinoid remains. In the northern limits of Nora Springs the member becomes highly magnesian and passes below water level. At their next northward appearance, this and the beds above are dolomitized, nearly barren, and almost inseparable.

4a—POTERIOCRINUS ZONULE

This zonule is typically developed at Rockford, where it is represented by a series of calcareous shales, thin-bedded, shaly limestones, and lenses of encrinital limestone. Its most northward occurrence is at the Rock Grove Mill where it is 6 inches thick in contrast with 54 inches at Rockford. The predominant fossil is an undescribed *Poteriocrinus*, the calyx plates and stem ossicles of which occur by the thousands, in places making thin lenses of encrinital limestone. In the shaly layers fossils are abundant, particularly *Trigonotreta shellrockensis* n. sp. and *Stropheodonta scottensis* n. sp. With these are found casts of many molluscs and numerous bryozoans. Coral and stromatoporoids are comparatively rare.

4b—STEREOCRINUS ZONULE

This is the southward continuation of the Poteriocrinus zonule. It is best developed west of Marble Rock where it is composed of shale and shaly limestone. Like the Poteriocrinus zonule it is rich in fossils, about one-third of them being typical of the Poteriocrinus faunule. Its greatest thickness west of Marble Rock is 36 inches; there its base is in contact with the Cedar Valley strata. It thins rapidly to the east and south and is absent at Roseville and Greene.

3a—AGELACRINITES ZONULE

This name is given to an association of fossils which are found attached to the eroded surface of the Aulopora zone; in the Baumgardner phase the Pachyphyllum zonule being the substratum, and at Nora Springs the Gyroceras zonule. The most common fossil of this assemblage is the cystid, *Agelacrinites hanoveri* Thomas. With this there is another spe-

cies of the same genus as well as several species of *Aulopora, Hederella, Stomatopora, Spirorbis, Autodetus, Serpula, Crania* and other adnate types. This faunule is typically shown in the Baumgardner phase where apparently it has no stratum of its own, the fossils always being attached to the eroded surface of the stromatoporoids below or to the similarly eroded limestone matrix between. At Nora Springs it is also well shown, but in addition to being attached to the substratum, the same species also are found in a thin shaly stratum some 4 inches thick lying above the Aulopora zone. Here, too, there are several species of brachiopods not found in the Baumgardner phase.

I.—AULOPORA ZONE

This zone, part of which forms the "Stromatopora Reef" of Calvin's Nora Springs section, is one of the most unstable zones of the entire Shellrock. It is typically developed at Nora Springs, where it attains a maximum thickness of nearly 15 feet. To the north and west it appears above water level at several points between Nora Springs and Rock Falls, and in this distance shows but little decrease in thickness even though it becomes more or less magnesian with its fossils poorly preserved. South and east of Nora Springs it thins rapidly, the upper calcareous portion or "Stromatopora Reef" disappearing completely in the Baumgardner phase and the lower dolomitic portion disappearing northwest of Marble Rock. This eastward thinning apparently is due largely to erosion of the upper surface although the overlap on the underlying Cedar Valley strata undoubtedly had had effect in the more southern and eastern phases.

2a—GYROCERAS ZONULE

This member is shown only at the type exposure of the substage along the river cliff in the western part of Nora Springs. It is composed of hard, semilithographic limestone, about 5 feet in thickness near the middle of the cliff but absent at its southern end, where it has merged with the zonule beneath. It thins rapidly toward the northern end of the cliff, its final northward extent being represented by magnesian shale. The faunule is meager, consisting almost en-

tirely of molluscs of which two undetermined species of *Gyroceras* are most common.

2b—PACHYPHYLLUM ZONULE

This is the dominant member of the zone in the Nora Springs phase and is represented by hard, heavy-bedded limestone which is crowded with colonies of spheroidal stromatoporoids. Several species of *Aulopora* are common as well as many corals and brachiopods. The maximum thickness of this zonule, nearly 11 feet, is shown directly south of Nora Springs; southeastward it thins rapidly and disappears in the Baumgardner phase. In northwestern Nora Springs it also thins, being represented at the northern end of the type exposure by 36 inches of limestone in two heavy beds. Northwest of this the faunule has not been found.

2c—PLATYSCHISMA ZONULE

Like the preceeding zonule this consists of heavy bedded limestone, seen only in western Nora Springs. At the northern end of the type exposure, it is some 3 feet thick, holding that thickness to the south where it merges and intergrades with the Pachyphyllum zonule. Spheroidal stromatoporoids are occasional but they are much smaller than in the southern end of the cliff. Corals are more or less common throughout the zonule, while at the northern end of the cliff the member contains numerous beautifully preserved molluscs. Of these an undescribed form of *Platyschisma* is very common.

2d—CRASPEDOPHYLLUM ZONULE

Magnesian limestone and shaly dolomites which are typically developed in the Sherman Bluff phase, the zonule being equivalent to the more southern Pachyphyllum zonule. Stromatoporoids, however, are absent. In their place there are hundreds of colonies of an undetermined species of *Craspedophyllum*, the colonies of which are from 6 to 18 inches in thickness and often 7 feet in diameter, with these are associated several corals found also in the Pachyphyllum zonule as well as numerous brachiopods of species not found in more southern zonules.

This zonule is more or less continuously exposed from Sherman Bluff to Rock Falls. The corals, however, are largely absent in the more northern phases, their place being taken by branching indiotromids similar to those found in the upper portion of the Pachyphyllum zonule at Nora Springs and in equivalent beds at Mason City.

1a—DOLOMITE ZONULE

Dolomitic beds with occasional layers of shale, more or less continuous along the Shellrock from Rock Falls to the mouth of Losee creek west of Marble Rock in which distance they form the basal member of the Shellrock, being in contact with the eroded surface of the Cedar Valley. These beds obtain their greatest thickness, 8 feet, in the Baumgardner phase, although this thickness is nearly equalled in the Sherman Bluff and Rock Falls phases. At Nora Springs they measure less than 4 feet in thickness. Throughout the area in Floyd County where these beds are exposed they have proven to be barren, being distinguished adequately by their lithologic characters.

B—PHASE DESCRIPTION

1—NORA SPRINGS PHASE

Since the Shellrock Stage is typically developed along the Shellrock River between Nora Springs and Rockford, with the type exposures in the immediate vicinity of Nora Springs, the first phase to be discussed is that to which the name Nora Springs may well be given.

In and near Nora Springs the Shellrock strata form a series of steep cliffs rising from either bank of the river and

19 Resting upon the eroded surface of the Nora substage in the extreme western portion of Nora Springs, there are from three to ten feet of the basal blue shales of the Juniper Hill formation, while slightly over a mile due west of Nora Springs the entire thickness of the Juniper Hill is shown and is capped by the Cerro Gordo substage and a remnant of the Owen substage of the Hackberry. These beds are continuous from this point westward to Portland and southward nearly to Lime Creek. Their northern and northwestern limits are obscured by drift.

extending from the northwestern limits of the town to the Rock Grove Mill, some three miles southeastward. In this area the beds are well exposed, no less than twenty excellent sections being offered. Most of these exposures are confined to beds of the Shellrock stage only, but along the river south of Nora Springs, and at the exposure in the western part of the town, the upper beds of the Cedar Valley stage rise above water level to form conspicuous ledges a few feet above water level.[19]

The Nora Springs phase can be most fully explained by giving in order the sections of the three type exposures of the substages which compose the Shellrock. The first of these, the type exposure of the Nora substage, is located at the "Junction" in the southwestern part of Nora Springs. Unfortunately here the upper zone is but poorly shown while the central (Platyrachella) zone is composed of but one member, thus in the number of zonules the Nora substage is not fully developed. The section follows:

NORA SUBSTAGE

Second Actinostroma Zone — INCHES

Pseudotectus zonule 58-62

Hard white limestone in one massive bed, composed almost entirely of crowded colonies of *Stromatopora*, *Actinostroma* and other stromatoporoids. Associated with these are many small brachiopods and molluscs and rare echinoid remains. These are to be found in the yellow, shaly matrix between the stromatoporoids.

PLATYRACHELLA ZONE

Unnamed zonule 60

Soft, yellow-brown, magnesian shale, distinctly stratified, weathering easily to a gritty yellow clay; apparently barren.

FIRST ACTINOSTROMA ZONE

Expansum Zonule 54-60

Hard white limestone in one massive bed, composed of laminar stromatoporoids, particularly *Ac-*

tinostroma expansum (H. & W.) A compound idiostromid common with occasional tabulate corals. The upper surface moderately undulating; lower highly so.

Unconformity

ROCK GROVE SUBSTAGE

Schizophoria Zone

Ulsterensis zonule 54-60

Firm, brownish, impure dolomite in several layers, which increase in thickness upward. Upper surface eroded and marked by channels and by domes 10 to 18 inches in diameter and 2 to 6 inches high. Upper portion contains abundant casts of *Spirifer ulsterensis* n. sp., *Schizophoria floydensis* n. sp. and other fossils. Full thickness not shown, the base being covered by sod.

The type exposure of the Rock Grove substage is located on the eastern bank of the Shellrock River a short distance southeast of Nora Springs, where the beds of the Shellrock Stage form a nearly vertical cliff along the river. In the upper beds of the section is an abandoned quarry. In general all of the beds are well exposed though the more shaly portions show a tendency to slump. The section is as follows:

NORA SUBSTAGE

Second Actinotroma Zone. INCHES

Pseudotectus zonule 48-54

Hard white limestone like that of the type exposure; fauna essentially similar.

Platyrachella Zone.

Unnamed zonule 72

Yellow brown, magnesian shale, unfossiliferous.

First Actinostroma Zone.

Expansum zonule 42-50

Firm, gray-buff limestone so crowded with stromatoporoids as to appear white. *Actinostroma expansum* (H. & W.) typical; *A. pulchra* less com-

mon than at Nora Junction. Lower surface strongly undulating.

Unconformity

ROCK GROVE SUBSTAGE

Schizophoria Zone

Ulsterensis zonule 54-60

Hard, brown, crystalline, and rather impure dolomite which tends to intergrade with the shale below. Upper surface deeply channeled and marked by domes from 1 to 3 feet in diameter and commonly 8 inches high. Casts of *Spirifer ulsterensis* n. sp. and *Schizophoria floydensis* n. sp. abundant; other species less common.

Atrypa zonule 90

Soft, blue-gray, magnesian shale distinctly stratified and somewhat indurated at the top where it intergrades with the dolomite above. Shale easily weathered, breaking down into a gritty blue clay. No fossils noted.

Paracyclas Zone.

Pterinea zonule 80

Soft, yellow, magnesian limestone or impure dolomite in one heavy bed, weathers to a gritty yellow clay and shapeless blocks, the more durable portions deeply pitted. No fossils noted.

Gomphoceras zonule 60

Hard, blue-gray, very durable limestone in thin, regular layers 1 to 2 inches thick, separated by like thickness of fissile gray shale. Casts of molluscs common; fish and crustacean (?) remains occasional. Conformable with the bed above and in places apparently intergrading with it.

Unconformity

MASON CITY SUBSTAGE

Lepidocentrus Zone

Camarophoria zonule 15

Soft, yellow-brown, argillaceous limestone in one

shattered bed which weathers to a gritty yellow clay or geest. Contains many species of rugose and compound corals, as well as abundant brachiopod and echinoderm remains. The most common forms are *Cyathophyllum floydensis* n. sp., *Phillipsastrea minutissima* (Webster), *Stropheodonta cicatricosa* n. sp. *Camarophoria paupera* n. sp. and *Gypidula* sp. The upper surface of the bed, where well shown, is pitted and more or less marked by hollow, rust-lined cavities.

Unconformity

Trigonotreta Zone

Cyrtoceras zonule 20

Hard, fine-grained, blue-gray limestone in one massive and very durable bed generally forming a ledge along the face of the exposure. Upper surface moderately undulating and occasionally iron stained. *Trigonotreta shellrockensis* n. sp. abundant; casts of molluscs common, as well as poorly preserved crinoidal remains.

Symbathocrinus zonule 8-10

Soft, grayish, shaly limestone in thin layers interbedded with fissile gray shale; upper and lower parts intergrading with the adjoining beds. Fossils abundant, chiefly disassociated crinoid plates and stem ossicles, and small brachiopods. Casts of *Gracilerectus* very common.

Decadocrinus zonule 64

Hard, drab, magnesian limestone in several irregular layers with occasional thin lenses of encrinital limestone. Full thickness not shown, since the base is below water level. Fossils rare or absent in the magnesian portion but abundant in the encrinital lenses. Several species and genera of crinoids noted as well as many undetermined brachiopods and pelecypods.

The third section given for this region is that of the type exposure of the Mason City substage, in the western part of the town of Nora Springs. A section of this cliff was given by Calvin.[20] Virtually all of the beds exposed here belong to the Mason City substage; they form a steep cliff rising directly from the water and extending along the eastern bank for nearly half a mile. Although the strata are affected by gentle folds, their general plane is nearly level. The cliff is higher at its northern end, however, and there the lower part of the Rock Grove substage is shown capping the Mason City. The section follows:

ROCK GROVE SUBSTAGE

Schizophoria Zone — INCHES

Atrypa zonule 30

Soft, blue-gray, magnesian shale, distinctly stratified where freshly exposed but generally represented by a belt of gritty blue clay. Full thickness of the bed unknown, since it extends beneath the sodded slope above; its base apparently is conformable with the bed below. No fossils noted.

Paracyclas Zone

Pterinea zonule 46

Soft, buff, magnesian limestone or shaly dolomite in one considerably shattered bed, apparently conformable above and below. A single poorly preserved cast of *Pterinea* sp. the only fossil noted.

Gomphoceras zonule 30

Hard, blue-gray, compact limestone in thin, regular layers 1 to 3 inches thick, interbedded with layers of fissile gray shale of nearly equal thickness; lower surface moderately undulating. Casts of molluscs and fish remains common; small spheroidal stromatoporoids rare.

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20 Iowa Geol. Surv. Vol. 7, p. 154; 1897.

Unconformity

MASON CITY SUBSTAGE

Lepidocentrus Zone.

Camarophoria zonule 18

Soft, yellow, argillaceous limestone in one shattered bed which weathers to a gritty clay. Upper surface of the bed moderately undulating and marked by numerous hollow, rust-lined cavities. Fossils abundant and well preserved: compound corals make up the bulk of the fauna, but not the greatest number of species. The most common forms are *Camarophoria paupera* n. sp., *Hyothyridina magister* n. sp., *Stropheodonta cicatricosa* n. sp., *Strobilocystites schucherti* Thomas, *Cyathophyllum floydensis* n. sp., *Alveolites* sp. and several forms of *Phillipsastrea*. *Lepidocentrus thomasi* n. sp. is common as well as other echinoid remains. The whole fauna numbers over 100 species.

Alhyris zonule 24

Hard, blue-gray, crystalline limestone, generally in two layers, conformable with the bed above and intergrading with it at the southern end of the cliff. At the northern end of the cliff this member thickens considerably and becomes argillaceous. Laminar and hemispherical stromatoporoids abundant; brachiopods numerous, similar to those in the bed above.

Unconformity

Trigonotreta Zone.

Cyrtoceras zonule 24

Hard, fine-grained, blue-gray limestone, in one bed; generally frost shattered; upper surface somewhat eroded and iron stained. *Trigonotreta shellrockensis* n. sp. abundant; several species of cephalopods and pelecypods common, as well as poorly preserved crinoidal remains. This bed is thickest at the southern end of the cliff.

Symbathocrinus zonule 6-8
Soft, shaly, blue-gray limestone with fissile, gray shale, intergrading more or less with the beds adjoining. Fossils abundant, consisting largely of scattered crinoidal remains, small brachiopods and many fucoidal casts.

Decadocrinus zonule 50
Soft, light buff, shaly and rather magnesian limestone in one shattered bed, attaining its greatest thickness at the northern end of the cliff. Apparently barren.

Agelacrinites zonule 0-6
Soft, yellow, gritty shale in thin layers which to the north become a magnesian limestone; absent at the southern end of the exposure though its fauna adheres to the eroded surface of the bed below. Its fauna consists largely of adnate forms —*Crania*, *Agelacrinites*, *Aulopora*, etc. At the northern end these and numerous other brachiopods, the most common of which is an undetermined *Platyrachella*.

Unconformity

Aulopora Zone.

Gyroceras zonule 0-48
Hard, light-buff, lithographic limestone in one or two beds, thickest near the center of the exposure. To the north it feathers out, while to the south it intergrades with the bed below. Upper surface eroded and undulating; lower conformable with the bed below. Fauna largely molluscan; two large, undescribed species of *Gyroceras* the commonest forms.

Pachyphyllum zonule 36-96
Hard, white, compact limestone with occasional thin shaly layers. At the southern end of the cliff it is in one massive bed nearly 8 feet thick, crowded with colonies of spheroidal stromatopor-

oids. Here, due to the absence of the Gyroceras zonule, its upper surface is strongly eroded. To the north the bed becomes divided into four nearly equal beds the upper two of which carry the typical stromatoporoids. Other typical fossils of this bed are corals of the genera *Cyathophyllum, Craspedophyllum, Alveolites, Diphyphyllum, Cladopora* and *Pachyphyllum.*

Platyschisma zonule 36

Limestone similar in texture to the above and being the northward extension of the two lower layers of that bed. Contains many molluscs the most common of which is an undescribed *Platyschisma.*

Dolomite zonule 40-46

Hard, buff, crystalline dolomite with occasional locally developed layers of argillaceous limestone, gritty shale, and sublithographic limestone. Upper surface of this bed generally poorly defined and tends to intergrade with the bed above; base sharply unconformable on the Cedar Valley beds below. No fossile noted.

Unconformity

CEDAR VALLEY STAGE 84

Hard, white, durable, lithographic limestone, apparently slightly brecciated, extending below water level; its upper surface strongly undulating. This bed can be divided in three parts. The uppermost of these, some 15 inches thick, is a hard lithographic limestone, charged with rugose and compound corals. This portion is shown only along the northern portion of the exposure. Nearly 25 forms of corals from this bed have been studied; not one species and but few genera are found in the overlying Shellrock beds. Beneath this, and separated from it by a stylolitic bedding plane are some 3 feet of mottled, lithographic limestone which appears to be nearly barren. Beneath this,

and likewise separated by a stylolitic bedding plane is a bed of hard, drab, crystalline limestone in one considerably shattered bed which extends below water level. It is rich in fossils nearly all of which are brachiopods similar to those found in the corresponding horizon at Marble Rock and Greene. Of the 10 species found here, none occur in the Shellrock.

The total thickness of each substage at any one point is: Nora, 15 feet; Rock Grove, 24 feet; Mason City, 22 feet.

2—BAUMGARDNER PHASE

Southward from Rock Grove Mill the valley of the Shellrock widens and the hills recede from the river and become less steep. Exposures are more widely scattered and offer poorer sections than those near Nora Springs, rarely showing more than one substage. Enough exposures exist, however, to allow tracing of the beds nearly to the northern limits of Rockford.

Changes in the strata appear at the Rock Grove Mill, three miles southeast of Nora Springs. Here the Eatonia zonule of the Lepidocentrus Zone appears: 6 inches of soft, shaly limestone carrying virtually the same faunule that it bears in the phases farther south. The Mason City substage is further modified by the appearance of the Poteriocrinus zonule at the base of the Trigonotreta zone, and though here a limestone, its fauna is nearly the same as in the shaly Rockford phase. The Pachyphyllum zonule of the Aulopora zone is but 6 feet thick. From the Rock Grove Mill to the site of Baumgardner's Mill, 2 miles farther southeastward, the members of the Mason City substage show few changes, and these consist wholly of variations in thickness of the different zonules. Thus the Eatonia zonule becomes nearly 2 feet in thickness and the Poteriocrinus zonule shows similar increase. The Lepidocentrus zone is also represented by the Cladopora zonule which is somewhat thinner than at Rock Grove and considerably thinner than the corresponding Camarophoria zonule at Nora Springs. The most important feature of the Baumgardner phase is the thinning and final disappearance

of the Pachyphyllum zonule of the Aulopora zone. At Baumgardner's Mill an anticline brings up the uppermost beds of the Cedar Valley strata which correspond to the lower two parts of these beds in the Nora Springs section, (No. 1, p.348).

Changes in the upper two substages are also noted. The Rock Grove has added a western phase of the Productella zonule, which appears at the top of the Pterinea zonule. The Nora substage begins to assume its typical character, for though the upper and lower beds are unchanged, the Platyrachella zone is here divided by a northward extension of the Syringopora zonule which separates the two shale zonules. Faunally these beds differ little from the Nora Springs phase.

As has been said, the Shellrock beds are nowhere shown completely, but the Baumgardner phase may be considered to be typically developed in the southwest quarter of section 28, T. 96 N., R. XVIII W., where the entire Mason City is present above the uppermost Cedar Valley beds. The various beds of the Rock Grove substage are best shown about a half mile to the north, while the Nora is completely shown about a mile southeast of Baumgardner Mill. The thickness of the three substages at these localities is: Nora, 15 feet; Rock Grove, 19 feet; Mason City, 29 feet. This is the greatest thickness of the Mason City in Floyd County, representing an increase of 7 feet over the Nora Springs phase. The Nora, however, is unchanged, while the Rock Grove has suffered a decrease of 5 feet.

3—RUDD PHASE

Traces of this phase appear in the Rock Grove substage of the Baumgardner phase, but it is not till the valley of Flood creek is reached, four miles to the northeastward, that the typical Rudd phase appears. Here, near the town of Rudd, the stream has cut through the drift and excavated a channel some 20 feet deep in the upper beds of the Shellrock Stage. Farther from the town the valley walls are low and gradual in slope, and the exposures unsatisfactory, since they seldom show more than one zonule.

In this phase the Mason City substage is poorly shown. The Lepidocentrus zone is known, being represented by an

eastern phase of the Cladopora zonule. The Eatonia zonule is missing, as at Nora Springs, allowing the Cladopora zonule to rest unconformably upon the Cyrtoceras zonule of the Trigonotreta zone. Faunally the beds show little change from the Baumgardner phase.

The Rock Grove substage, however, is exceptionally well developed and is more complex than in the Nora Springs and Baumgardner phases. The Paracyclas zone has added some 3 feet of shaly limestone carrying an abundant molluscan fauna, and in the upper portion many brachiopods; the Pterinea and Gomphoceras zonules, although somewhat thinner than along the Shellrock, preserve their lithologic character.

The upper Schizophoria zone is variously charged. Like the underlying zone, it has added another zonule, the Loxonema, but this increase is more than equalled by the thinning of the upper or Ulsterensis zonule. Here the heavy-bedded dolomite, so conspicuous at the top of this member at Nora Springs, is largely eroded away; and since it carries most of the fauna, the zonule at Rudd is sparingly fossiliferous. The Atrypa zonule preserves much the same character and thickness that it shows on the Shellrock. Beneath it, and forming the base of the zone, lies the new member, the Loxonema zonule, nearly 18 inches thick. The faunule of this bed is rich, the three dominant species being *Schizophoria floydensis* n. sp. *Loxonema* sp. and *Diaphorostoma* sp., the first making up nearly half the specimens found. There are some thirty other bryozoans, brachiopods and molluscs, few of them found in the underlying Mason City beds. The thickness of the Rock Grove in this phase is 17 feet.

The Nora substage, though poorly shown in the immediate vicinity of Rudd, appears almost in entirety one mile to the north and west. The second Actinostroma zone retains the faunal and lithologic character which it shows at Nora Springs, but is somewhat thinner. Beneath it is a gritty, yellow, magnesian shale forming the Platyrachella zone, while beneath this is a bed of yellow-brown, argillaceous limestone corresponding to the first, or lower, Actinostroma

zone. This differs markedly from the phases shown along the Shellrock, and because of the abundance of *Prismatophyllum oweni* n. sp. it is termed the Prismatophyllum zonule. The laminar stromatoporoids characteristic of this horizon along the Shellrock are almost absent, their places being taken by corals, which include two species of *Phillipsastrea* and several of *Ptychophyllum, Alveolites,* and *Cladopora* in addition to the *Prismatophyllum.* There also is a rich brachiopod and echinoderm fauna whose species are not typical of this horizon farther west. The entire thickness of the Nora substage here is but 11 feet.

About six miles southeast of Rudd, along a road cutting west of the Flood creek channel, beds of Shellrock age are exposed, which extend from the top of the Gomphoceras zonule to the top of the first, or lower, Actinostroma zone of Nora. In appearance these beds are very similar to the Rudd phase. The Nora is represented by a remnant of the Prismatophyllum zonule, which though only 12 inches thick (compared with 36 at Rudd), carries the same faunule. The Ulsterensis zonule is almost absent and the shale beneath is markedly thinner. The Loxonema zonule is replaced by the Crania zonule, a much shalier stratum, characterized by abundant bryozoans and brachiopods. Molluscs apparently are absent, but there are numerous echinoderms. The Productella zonule is much the same as at Rudd.

About one mile southeast of this cut, and directly east of Rockford, beds of the Mason City substage, as well as the upper beds of the Cedar Valley, appear along the banks of Flood creek, though they are too badly shattered and too poorly exposed to give a section. No other exposures are known along Flood creek until Roseville, 7 miles southeast, is reached, the intervening territory being deeply covered by drift.

4—ROCKFORD PHASE

From Baumgardner Mill to Rockford the valley of the Shellrock is broad, with gently sloping hills some distance from the river, in whose flood plain are but few exposures. At Rockford the valley again narrows, the hills rising direct-

ly from the river. The rocks lie in a series of broad, low anticlines in which the upper Cedar Valley is again exposed; and above them, beds extending to the top of the Shellrock. On the banks of Lime Creek, west of Rockford, the upper beds of the Shellrock are shown, as well as the lower part of the Juniper Hill formation. This elevated, slightly folded area extends to the confluence of the Lime Creek and Shellrock, south of which the valley of the Shellrock again widens.

The Rockford phase is typically shown on the eastern (left) bank of the Shellrock southeast of Rockford. A few of the beds are obscured by talus, but these are well exposed along Lime Creek south and west of the town, so that by combining these two sets of exposures the complete sequence is obtained.

Compared with the Baumgardner phase, three miles northwest, the chief differences shown by the Nora substage are a thickening of the various zonules and a greater abundance of fossils. This is especially true of the Pseudotectus zonule at the top of the Nora, and of the Schuchertella zonule at the base of the Platyrachella zone, both of which here carry rich and varied faunas.

Several characters of the Rock Grove substage recall its development in the Rudd phase; both the Loxonema and Productella zonules are present, although somewhat thinner than at Rudd. The Ulsterensis zonule of the Schizophoria zone has much the same thickness and fauna as at Nora Springs, but it is separated from the overlying Nora by a member not present in any other phase. This is the Strobilocystites zonule, a bed of yellow argillaceous limestone charged with corals, brachiopods and echinoderms. It is developed only on the eastern bank of the Shellrock, not being shown along Lime Creek west of Rockford, where the Nora rests directly upon the Ulsterensis zonule. This new member is unconformable with the Nora substage and can be traced south and east some three miles, and then is removed by erosion.

The Mason City strata here differ greatly from those at Baumgardner Mill. The Lepidocentrus zone is again represented by the Camarophoria zonule, with much the same

lithologic character and fauna that mark it at Nora Springs: the Athyris zonule of the Nora Springs phase is lacking at Rockford but the Eatonia zonule consists of more than three feet of firm, yellow-buff limestone, bearing a fauna apparently the same as in the Baumgardner phase. The Trigonotreta zone thickens, the lower shaly portion, (Poteriocrinus zonule) increasing to some four feet and carrying a very rich and varied fauna. Above it lie some 8 or 9 feet of buff limestone, the Stropheodonta zonule, carrying a fauna composed largely of brachiopods and molluscs. The Aulopora zone is represented only by the lower or Dolomite zonule which here reaches a thickness of nearly 9 feet.

The thickness of the Nora substage in these exposures is 16 feet, of the Rock Grove 18 feet, and of the Mason City 27 feet. The Nora reaches nearly its maximum thickness while the other two substages show a slight decrease when compared with the Nora Springs and Baumgardner phases.

5—MARBLE ROCK PHASE

Southward from Rockford the valley of the Shellrock offers virtually no exposures for nearly three miles, chiefly because of a broad syncline which carries most of the Shellrock strata below water level. Except for one exposure of the Nora, at Fisher's bridge, the beds do not appear on the western side of the river until Losee creek is reached, two miles west of Marble Rock. On the eastern bank of the Shellrock the beds start to rise near the mouth of Ballard creek, three miles southeast of Rockford, and are exposed more or less continuously along the Shellrock to Marble Rock, rising gradually until in the town the base of the Shellrock beds is nearly forty feet above water level.

In this distance considerable changes appear throughout the stage. In the series of exposures which extend nearly to Marble Rock, the Nora substage shows rapid thinning of its various members. The second, upper, Actinostroma zone apparently does not reach Marble Rock, being noted last some two miles northwest of the town. The Platyrachella zone becomes less than 3 feet in thickness, the lower shale (Schuchertella zonule) being the most persistent and continuing

nearly to the limits of Marble Rock. The lower (first) Actinostroma zone, represented by a southern phase of the Prismatophyllum zonule, is present but is only about 2 feet thick.

The Rock Grove substage is more readily traced, its several zonules appearing in nearly all of the exposures. At Ballard creek the Ulsterensis zonule at its top consists of a thin remnant which is entirely absent where this horizon is next exposed two miles southeastward, where the lower portion of the Nora rests upon the shaly Atrypa zonule. The Productella zonule continues nearly to Marble Rock, but the Loxenema zonule disappears a short distance south of Ballard creek. About a mile north of Marble Rock the Atrypa zonule feathers out, allowing the first Actinostroma zone of the Nora to rest upon the here eroded surface of the Productella zonule. This is the most easterly point at which these two beds have been found. The Pterinea and Gomphoceras zonules at the base of the Rock Grove continue southward through this area with but little change.

With the exception of these two zonules, the Nora and Rock Grove substages are not shown on the western bank of the Shellrock. On the other hand, although exposed at several points on the eastern bank, the Mason City substage is best shown along the western side of the stream, particularly in the vicinity of Losee creek. The beds are exposed at several points in this vicinity, and at the most westerly of these there is a remnant of the Dolomite zonule. This does not exceed a foot in thickness, and generally is found in the troughs of the eroded Cedar Valley below; less than a mile southeastward it is absent. The Poteriocrinus zonule, at the base of the Trigonotreta zone, is replaced by the Stereocrinus zonule, which, though lithologically similar, carries a distinct faunule. Half a mile southeast of the mouth of Losee creek, this zonule forms the base of the Shellrock, resting upon the Cedar Valley beds. The Cyrtoceras, Symbathocrinus, and Stropheodonta zonules, composing the rest of the Trigonatreta zone, are merged together in a single bed less than 5 feet thick, and the Lepidocentrus zone consists of one thin member

greatly resembling the Cladopora zonule of the Baumgardner Phase. Northwest of Marble Rock, the shaly Stereocrinus zonule is less than 2 feet thick, compared with 3 feet at Losee creek.

Near Marble Rock the beds of the Cedar Valley stage are conspicuous, forming steep cliffs which are capped by the stromatoporoidal lithographic beds which characterize the upper portions of the stage. Because of their durability, these beds stand out boldly, while the overlying Shellrock beds, being softer, are more easily weathered—one of the reasons Shellrock beds have not previously been detected here. The other is that they must be sought on the gentle slopes back of the cliffs bordering the stream.

While the full thickness of the upper two substages of the Shellrock are not shown at Marble Rock, measurements of the different members at the point nearest Marble Rock may prove of interest. The amount of decrease as compared with the Rockford phase is also given. These measurements are: Nora: thickness, 6 feet, decrease 10 feet; Rock Grove: thickness 6 feet; decrease 12 feet; Mason City, (at Losee Creek) thickness 9 feet, decrease 19 feet. There is a further decrease of 18 inches in the last named at Marble Rock, caused by thinning of the basal Stereocrinus zonule.

6—ROSEVILLE PHASE

Near Roseville, a hamlet on Flood creek, five miles northeast of Marble Rock, a phase of the Shellrock beds is shown which is very similar to that of the Marble Rock phase. The Nora substage apparently is absent and only the lowermost (Gomphoceras) zonule of the Rock Grove substage is shown. The entire thickness of the Mason City substage is present, resting, as at Marble Rock, upon the eroded surface of the Cedar Valley with pronounced unconformity.

The Lepidocentrus zone here is but 7 inches thick and carries a faunule closely allied to that of the Cladopora zonule. As at Marble Rock, the Eatonis zonule is absent and the three zonules of the Trigonatreta zone are united into one bed, their separation being difficult. The shaly Stereocrinus zonule is

absent, allowing the Stropheodonta zonule to rest upon the Cedar Valley strata.

The thickness of the Mason City substage is about 6 feet, a decrease of 3 feet in the five miles from Marble Rock. This rate of decrease would allow the substage to extend some ten miles farther eastward before its final disappearance, but is unknown along the Cedar River in the region thus indicated. That the beds ever extended more than half this distance is doubtful in view of the rapid decrease from Rockford to Marble Rock.

7—GREENE PHASE

Exposures are rare on the eastern side of the Shellrock from Marble Rock southward to Greene, the region being deeply covered by drift. On the western side, however, exposures are fairly continuous, the strata lying in a syncline which brings the top of the Cedar Valley but a few feet above water level. The Shellrock beds are frequently exposed but are so thin that they do not form cliffs like those at Nora Springs and Rockford. Only the Mason City and lower portion of the Rock Grove substages are exposed, the southernmost exposure of the Nora now known being almost two miles due south of Marble Rock, where a remnant caps a hill near the center of section 20 of Union township.

About a mile northwest of Greene the strata rise rapidly; near Greene the top of the Cedar Valley is from 30 to 50 feet above the Shellrock river. Here, as at Marble Rock, the lithographic upper beds form steep bluffs which extend southward on either side of the river nearly to the mouth of Flood Creek.

Shellrock strata are exposed on the west bank of the stream northwest of Greene, at the point where the beds start to rise; from there, however, the exposures trend to the southwest and Shellrock strata are no longer exposed along the banks of the river.

In sections 13 and 14 of Coldwater township, Butler County, the strata are again affected by a syncline, so that along the banks of Coldwater creek beds of the Shellrock reappear as isolated outliers whose general trend is east and west. The

full thickness of the Mason City substage is shown; it rests, as at northern points, on the eroded Cedar Valley, and is covered by the lower portion of the Rock Grove substage. Exposures lie on either bank of the stream, but beds higher than the Paracyclas zone have not been found.

The Cedar Valley beds resemble those at Marble Rock, the upper portion being a lithographic limestone bearing a fauna composed largely of a spheroidal stromatoporoids, with occasional rugose corals, and more commonly, brachiopods. The unconformity at the top of these beds is marked, the vertical inequalities sometimes amounting to a foot. In view of the extreme durability of these limestones this must signify a considerable period of erosion.

The Mason City substage consists of little more than a remnant. As usual, the Lepidocentus zone (Cladopora zonule) forms the top, being here some 9 inches thick. A remarkable feature of this phase is the reappearance of the Eatonia zonule. It bears the typical faunule, and has the same lithologic character that marks it in the Baumgardner phase. The members of the Trigonotreta zone again are separated, the zone being represented by the Cyrtoceras, Symbathocrinus, and Stropheodonta zonules, carrying much the same faunules that they hold at Rockford. The basal, shaly Stereocrinus zonule is absent, as in the Roseville phase, allowing the Stropheodonta beds to rest upon the Cedar Valley.

Both the Pterinea and Gomphoceras zonules of the Paracyclas zone are present, each being lithologically similar to the Rockford and Nora Springs phases. The total thickness of the Mason City substage in this phase is slightly less than 4 feet, while the exposed portion of the Rock Grove measures less than 6 feet.

Shellrock beds are again indicated in the central and western parts of Section 1 of Benezette township, Butler County. These apparently represent another outlier similar to those just mentioned. No definite exposures of the beds are known, but on the crests of the hills along the south side of Coldwater creek blocks of limestone have been plowed up which

are of the lithologic character of the Lepidocentrus zone. They carry as fossils *Cyathophyllum floydensis* n. sp., *Phillipsastrea minutissima* (Webster) and laminar stromatoporoids such as characterize that zone in the Nora Springs phase. Evidently this is a southward extension of the Camarophoria zonule.

The contact of the Shellrock beds with the Cedar Valley is not shown, although the latter offers numerous good exposures along the creek in the central part of the section. The top of the Cedar Valley here is composed of a sublithographic limestone with much interbedded shale. This is rich in fossils, most of which are corals, apparently identical with those found in the uppermost bed of the Cedar Valley at Nora Springs. With these are occasional branching idiostromids and small crinoid stems. This evidently is the horizon referred to by Arey[21] in his report of Butler County. Beneath this bed is the horizon of lithographic beds carrying a fauna of spheroidal stromatoporoids.

8—REED CREEK PHASE

Returning again to Nora Springs, the succession of beds in the Shellrock stage now may be traced northward and westward along the Shellrock River to Rock Falls.

From the northwestern limits of Nora Springs the beds dip rapidly westward, while the river valley becomes shallow. For nearly two miles only the Nora and the upper part of the Rock Grove substage are exposed. Some two miles northwest of Nora Springs, on the west bank of the river, an anticline brings up the Rock Grove and upper Mason City beds. This point is about a half mile southeast of the mouth of Reed creek and forms the typical locality of that phase.

In this distance the beds change considerably. The upper Actinostroma zone becomes thicker and loses it fauna of small molluscs and brachiopods, though retaining the laminar stromatoporoids. Because of the aburdance of an undescribed *Stromatopora* it is here termed the Stromatopora zonule. The Platyrachella zone again assumes the character

21 Iowa Geol. Surv. Vol. 20, p. 30; 1910.

shown at Rockford, being divided by a bed of shaly dolomite (Ptychophyllum zonule) which first appears near the Floyd County line with a thickness of 10 inches which increases to 20 in the Reed Creek phase. Its faunule is composed largely of brachiopods, particularly *Platyrachella ballardi* n. sp. of a form very similar to that from the Schuchertella zonule at Rockford. The shale beneath, which forms the Schuchertella zonule farther south, is here highly magnesian, containing fossils only as casts. Of these the most common is *Platyrachella ballardi* n. sp., the specimens, however, being much larger than those from Rockford. Casts of a rugose coral are also common.

The most important change takes place in the lower Actinostroma zone. Near the Floyd County line a thin bed of brown limestone appears at the top of this zone, being separated from the Expansum zonule beneath by a strong bedding plane. This bed increases until in the Reed Creek phase it is nearly 2 feet thick. This is termed the Macgeea zonule, the faunule of which consists almost entirely of corals. At the base there are abundant stems of a robust *Cladopora* and a much smaller, cylindrical *Alveolites*. Toward the top these are replaced by thousands of rugose corals belonging to the genera *Macgeea, Ptychophyllum, Cyathophyllum* etc. with occasional masses of *Phillipsastrea* and *Prismatophyllum* while a slender undetermined idiostromid is also locally abundant. With the increase in thickness of the Macgeea zonule the Expansum zonule becomes thinner, dropping from 54 inches at the County line to about 24 inches at Reed Creek. At the same time it changes from a hard gray limestone to a dirty brown, submagnesian limestone, while the laminar stromatoporoids typical of the Expansum zonule gradually give way to spheroidal forms, some of which attain a diameter of nearly 3 feet. Coincident with this is the appearance of brachiopods, particularly a flattened form of *Trigonotreta shellrockensis* n. sp. This member is widely different from the Expansum zonule.

The Rock Grove substage is well exposed in this phase but is considerably modified. The uppermost (Ulsterensis)

zonule begins to change in character near the Floyd County line. It retains its impure dolomitic character but becomes more thinly bedded and shows a considerable decrease in thickness. *Spirifer ulsterensis* n. sp., so typical in the southern phases, gradually disappears and for a short distance the zonule is nearly barren. At Reed Creek it again becomes fossiliferous, bearing an undetermined *Conularia* and several species of fish; it may be termed the Conularia zonule. The underlying shaly Atrypa zonule retains its character but becomes thinner. The Paracyclas zone is well shown at the anticline already mentioned. Here it is composed of two zonules: the upper, 18 inches thick, is a thin-bedded dolomite which represents the Pterinea zonule, while the lower, composed of hard brown limestone in thin layers represents the Gomphoceras zonule.

Only the upper part of the Mason City substage is shown here and it is so heavily dolomitized that recognition of the members is difficult. Fossils are abundant but consist of casts or of calcite masses which show only the general form of the organism. *Cyathophyllum floydensis* n. sp., *Phillipsastrea minutissima* (Webster), *Camarophoria paupera* n. sp. *Hypothyridina magister* n. sp., have been identified as well as several other species which are typical of the Camarophoria member of the Lepidocentrus zone as it is developed at Nora Springs. Less than three feet of the Mason beds are exposed at this point, and probably but this one zone is present.

The thicknesses of the two upper substage in this phase are: Nora, 19 feet, an increase of 4 feet over the Nora Springs phase; Rock Grove 15 feet, a decrease of 9 feet.

9—BJORGASON PHASE

From the anticline of the Reed Creek phase the beds dip northward and the Mason City substage is not shown for a distance of about one half mile. A short distance north of the south line of Falls township, Cerro Gordo County, the Mason City reappears near water level and rises until the full thickness of the substage is shown. This elevation is held, with but minor changes, for over a mile northward, the strata being exposed on both banks of the river. In this dis-

tance the beds change so greatly that it is necessary to divide them into three phases to correlate properly the northern and southern sets of exposures.

The first of these, the Bjorgason phase, is best shown on the west bank of the Shellrock in the southeast quarter of section 35, T. 97 N., R. XIX W.—the locality at which the Mason City substage reappears. Here the beds form a steep cliff, rising directly from the river and affording a complete section of the Nora and Rock Grove substage as well as of the upper portion of the Mason City.

In the Nora substage the upper Actinostroma zone retains its characters of the Reed Creek phase. The Platyrachella zone consists of three zonules, the upper and lower shaly portions showing dolomitization, while the central (Ptychophyllum) zonule is represented by shaly dolomite which intergrades with the softer bed below; all of the zonules apparently are barren.

The lower Actinostroma zone, however, suffers the more marked changes. The Macgeea and Expansum (?) zonules of the Reed Creek phase are represented by two beds of soft, brown, finely crystalline dolomite. Beneath these another zonule appears slightly north of Reed Creek, thickening to the north and represented in the Bjorgason phase by 15 inches of dolomite similar to that above, but somewhat firmer. All of these zonules appear to be barren. In places the bedding planes between them assume the character of unconformities and the base of the lowermost zonule is strongly undulating.

The Rock Grove substage is well shown in a series of exposures leading up to the Bjorgason phase. From the Reed Creek phase northward the uppermost (Conularia) zonule can be traced; it thins from 30 inches to about 8 at its last exposure, about one fourth of a mile east of the present phase exposure. This thinning is caused by erosion, which in the Bjorgason phase has quite removed the zonule, allowing the Nora substage to rest upon the shaly Atrypa member. The two zonules of the Paracyclas zone are considerably modified, the upper (Pterinea) zonule consisting of thin-bedded dolo-

mite about a foot in thickness, while the basal (Gomphoceras) zonule becomes dark and heavy-bedded, and loses the shale partings typical of it in all southern phases.

The Mason City substage, in the Bjorgason phase, shows heavy dolomitization with attendant loss of fossils. The coralline faunule of the uppermost Camarophoria zonule is indicated by large masses of calcite, while the brachiopods appear to be absent; only one member represents the Lepidocentrus zone. Its base is marked by a strong bedding plane beneath which lie 4 feet of heavy-bedded, magnesian limestones which extend beneath water level. These apparently represent the Trigonotreta zone, but scarcity of fossils and the similarity of the beds makes it impossible to satisfactorily delimit the zonules.

In this phase the thickness of the Nora substage is 17 feet and of the Rock Grove, 10 feet. This shows a decrease of 2 feet in the former and 5 feet in the latter, from thickness in the Reed Creek phase.

10—SHERMAN BLUFF PHASE

The second phase in this vicinity is termed the Sherman Bluff phase. It is well shown along the east bank of the Shellrock, in a steep cliff beginning a short distance north of the Bjorgason phase and extending beyond the middle of section 35, a distance of about a quarter of a mile. Here uplift brings to view practically the full thickness of the Mason City substage, as well as the two substages above it.

The Nora substage shows little change from the Bjorgason phase, though at the north end of the cliff the three members of the Platyrachella zone are dolomitized. Except for the upper Actinostroma zone, the entire substage is barren.

The Rock Grove substage suffers considerable change. As in the Bjorgason phase, the Conularia zonule is absent, and the other member of the Schizophoria zone, the Atrypa zonule, becomes thinner, finally disappearing a short distance north of the main exposure. In the Paracyclas zone, the Pterinea zonule is either absent or has united with the Gomphoceras zonule to form a series of strata, which at the southern end of the cliff are thin-bedded, hard, brown, magnesian

limestones, but at the northern end are represented by firm, coarsely-crystalline dolomite, in heavy beds which contain much calcite. The entire substage is barren. At the next exposure northward the Schizophoria zone is absent.

This is the first point north of Nora Springs where a full section of the Mason City substage is available. The beds are more or less dolomitized and show a tendency to lose their lithologic distinctness, although enough fossils are known to permit separation of the zones. The uppermost division, the Lepidocentrus zone, is represented by some 40 inches of soft, fine-grained magnesian limestone which apparently represents but one zonule. The unconformity at the upper surface of the zone is pronounced; at the southern end of the cliff the base is marked by a strong bedding plane which becomes weak and obscure northward. The Trigonotreta zone is lithologically like the Lepidocentrus, and except for unrecognizable masses of calcite appears unfossiliferous.

The Aulopora zone is very well represented here, and is separated by an unconformity from the overlying Trigonotreta beds. This unconformity becomes less marked to the north and apparently is absent in the next phase. This zone here consists of two distinct zonules; the upper and by far the greater portion is composed of 9 feet of soft, buff, fine-grained magnesian limestone which is indefinitely bedded at the southern end of the cliff and virtually unstratified at the northern end. It is abundantly fossiliferous, the most common form being an undetermined *Craspedophyllum* whose colonies, sometimes crowded, often attain a thickness of 2 feet and a diameter of 7 feet. This coral is common in the equivalent horizon at Nora Springs, but in much smaller masses. With it here are found many brachiopods and molluscs similar to those of the Nora Springs phase. This member is termed the Craspedophyllum zonule.

The lower member of the Aulopora zone in this phase consists of dolomite, gray to nearly black in color, underlain by gritty magnesian shale which extends beneath water level. These beds are barren, but apparently are equivalent to the Dolomite zonule of the southern phases.

The thickness of the Nora substage in this phase is 14 feet; of the Rock Grove 8 feet; and of the Mason City, 25 feet. For the first two, these are the minimum thickness in the northern phases, while the Mason City, with its full thickness not known, exceeds by 3 feet its thickness at Nora Springs.

11—KEIDLE BLUFF PHASE

From the northern end of Sherman bluff to the next exposure is less than a quarter of a mile. This exposure is locally known as Vermilya's Bluff and is well figured by Calvin.[22] The lower portion of the bluff is composed of beds which show almost no traces of stratification. These beds range from the Craspedophyllum zonule to the base of the upper Actinostroma zone, the horizons being distinguishable at the northern end of the bluff, where they form a series of shelves. On the opposite bank, and slightly north of Vermilya's bluff is a series of undercut cliffs, known as Weitsie's Bluff, which extend nearly to the northern border of section 35. About half of the Craspedophyllum zonule is above water level at the northern end of these exposures.

At the south line of section 26, Falls township, the beds again are exposed on the east side of the river, in a series of low cliffs which show nearly the entire thickness of the Shellrock. This exposure, known as Keidle's Bluff, also is figured by Calvin.[23] The Mason City beds are clearly shown in the figure, comprising the lower half of the section, which appears as a talus slope, although the beds are indurated; their appearance being caused by the rough face of the beds. Above the shattered beds lies the full thickness of the Rock Grove substage as well as the lower Actinostroma zone of the Nora substage. This exposure is located in the southwest quarter of section 26, T. 97 N., R. XIX W.,—not the northwest quarter, as Calvin states.

Throughout the area between Keidle's and Sherman's Bluff the upper Actinostroma zone of the Nora preserves its lithologic and faunal character and can be traced almost con-

22 Iowa Geol. Surv. Vol. 7, p. 129, fig. 14; 1897.
23 Iowa Geol. Surv. Vol. 7, p. 129, fig. 13; 1897.

tinuously. The Playrachella zone is represented by one bed of dolomite which weathers to a gritty shale. The lower Actinostroma zone, as at Sherman's Bluff, is composed of three members, here fossiliferous. The upper and lower zonules contain numerous spheroidal stromatoporoids and a slender idiostromid like that of the Macgeea zonule of the Reed Creek phase. These stromatoporoids increase in size and abundance northward. The strata are much firmer than in the Bjorgason and Sherman Bluff phases and the major bedding planes have become unconformities.

The Rock Grove substage is represented by about 9 feet of uniform, hard, buff dolomite in rather distinct beds representing a northward extension of the Gomphoceras and perhaps the Pterinea zonules of the Paracyclas zone, and apparently barren. Their upper surface bears erosion domes sometimes over a foot in height, while their base is marked by a similar but weaker unconformity.

The Mason City substage is represented by buff, magnesian limestone, largely devoid of stratification. In places, as near the center of the exposure, a portion near the top shows stratification but it intergrades with the beds above and below, and forms no permanent horizon. Calcite forms are abundant as irregular masses and shapeless veins, some of which resemble corals and idiostromids, but rarely are recognizable. Brachiopods are common and easily identified, being of forms which are typical of the Craspedophyllum zonule with which these beds are correlated. Virtually no fossils have been found, but the upper, more stratified portion may be equivalent to the Lepidocentrus and Trigonotreta zones farther south. On the other hand, these zones, particularly the upper, may be absent, represented only by the erosion plane at the top of the substage. This horizon of unstratified buff, magnesian limestone persists from Vermilya's Bluff to Rock Falls, and is characterized by its abundant calcite. In certain places it is more definitely stratified than at Keidle's Bluff, but it cannot be divided.

In the Keidle Bluff phase the Nora substage is 20 feet thick, the Rock Grove 9 feet thick, and the exposed portion

of the Mason City 10 feet, the two upper substages showing a considerable increase over the Sherman Bluff phase.

12—ROCK FALLS PHASE

From the northwest end of Keidle's Bluff the beds dip westward, and the Mason City substage is not shown for nearly a mile. The other two substages are exposed in low cliffs which extend north of Rock Falls, on both banks of the river. In the sections which they offer the zonules of the Rock Grove and Nora may be traced readily.

Through this area the upper Actinostroma zone of the Nora does not change lithologically or faunally though it thins somewhat to the northward. The Platyrachella zone consists of barren dolomites which become rather shaly at Rock Falls. The lower Actinostroma zone consists of three zonules, the upper and lower of which contain abundant spheroidal stromatoporoids and slender idiostromids. At Rock Falls these fossils appear in the central member as well, although the colonies are comparatively scarce and small. The most important change in this zone is lithologic. Slightly west of Keidle's Bluff the uppermost zonule is represented by hard, fine-grained, light buff limestone. This character is sporadically shown at various points to the north. About one-half mile northward the central member shows but a few patches of dolomite in the limestone and so at Rock Falls the lower (first) Actinostroma zone is represented by three beds of hard, light-buff limestone bearing idiostromids and spheroidal stromatoporoids. The central zonule is considerably thickened and all of the zonules are separated by unconformities, the domes of which are sometimes two feet high.

The Rock Grove substage is represented by apparently unfossiliferous dolomites which vary areally in texture, color, and thickness of bedding, but which are everywhere delimited both above and below by very marked unconformities. These represent a northward extension of the Paracyclas zone, probably the Gomphoceras zonule. At Rock Falls they are some 10 feet in thickness and are composed of durable, crystalline dolomite, heavily and rather evenly bedded.

About a mile south of Rock Falls the Mason City beds are brought above water level by a series of small anticlines, and are almost continuously exposed northward to the limits of the town. Both the Craspedophyllum and Dolomite zonules are shown, the latter apparently nearly to its base. The Craspedophyllum zonule contains two apparently permanent layers, separated by unstratified, calcite-bearing beds of the same magnesian character shown at Keidle's Bluff. Northward even these calcitiferous beds become stratified, so that at Rock Falls practically the entire exposed thickness of the substage consists of definitely stratified, magnesian limestone of alternating calcite- and non-calcitiferous character. Fossils are uncommon in the lower portion, but those which have been identified are brachiopods typical of the Craspedophyllum zonule. At Rock Falls the uppermost calcitiferous beds resemble the bed near water level at Parker's Mill in Mason City, while many of the calcite bodies suggest the branching idiostromids found there.

At the exposure nearest Rock Falls the Nora is 22 feet thick, the Rock Grove 10 feet, and the Mason City (exposed) 22 feet, showing increases in the upper two substages.

Northward from Rock Falls the valley of the Shellrock is little more than a narrow trench, with the sodded slopes generally coming down to the banks of the river. Occasionally the Shellrock strata are lifted by small anticlines, through which the river has cut narrow gorges, and in these the upper portions of the Shellrock may be traced well into Worth County.

While no good exposures of the upper Actinostroma and Platyrachella zones of the Nora are offered, small outcrops along road cuts and on slopes well back from the river show that these zones are present to the north, although evidently somewhat thinner. The lower Actinostroma zone, or at least its lower zonules, are shown at most of the gorges along the river, the strata retaining much the character which they show at Rock Falls, although in places some of the beds are dolomitized.

The Rock Grove substage continues to be represented by the Paracyclas zone, which, from the heavy-bedded dolomites shown at Rock Falls, gradually alters to beds of sub-lithographic limestone with layers of dolomite. Such a phase is shown along the west bank of the Shellrock at the site of Foster's Mill, in the northwest quarter of section 29, T. 98 N., R. XIX W., where nearly 20 feet of strata are exposed, a section of which is given by Williams.[24] Here the lowermost zonule of the lower Actinostroma zone is represented by dolomitic limestone containing spheroidal stromatoroids. Beneath this is the Rock Grove beds, the upper few feet of which are dolomite, while the basal portion is a drab, fine-grained limestone of lithographic character. Beds of the Mason City substage are not known to be exposed north of Rock Falls.

The four phases just described show the complete transition of the lower Actinostroma zone from a single bed of laminar stromatoporoids in the Nora Springs phase, to a tripartite limestone zone bearing spheroidal stromatoporoids. The unconformities between the zonules also become marked. The transition of the Paracyclas zone from a shaly limestone to a sublithographic member is also indicated in the exposures east of Manly.

It is this same zone of spheroidal stromatoporoids at Mason City which Calvin[25] correlated with the "Stromatopora Reef" (Pachyphyllum zonule) of Nora Springs. In the immediate vicinity of Mason City (Parker's Mill, Kuppinger quarry, Belding quarry) these stromatoporodal limestones do form the tops of the exposures shown along the streams, and apparently end the section. At various points to the north and west, as well as at Parker's Mill, this zone of spheroidal stromatoporoids is overlain by a horizon of dirty brown, coarsely crystalline dolomite representing the Platyrachella zone; and upon this a zone of limestone bearing laminar stromatoporoids, the upper Actinostroma zone of this paper. The real equivalent of the Nora Springs reef (Pachyphyllum

24 Ia. Geol. Surv. Vol. 10, p. 348; 1900.
25 Ia. Geol. Surv. Vol. 7, pp. 145-146; 1897.

zonule) is represented at Mason City by dolomites, and at Parker's Mill by shales, which occupy a position but a few feet above water level at these points.

To add sections of the Mason City exposures would enlarge this paper unduly. Moreover, the finer relationships of the lower members at Mason City remain uncertain, and must be determined by study of the sections along Lime Creek from Rockford, in Floyd County, to Fertile in Worth County. They will furnish material for another paper.

BOOK REVIEWS

Rehder, Alford, "MANUAL OF CULTIVATED TREES AND SHRUBS HARDY IN NORTH AMERICA."—The Macmillan Co.

Considering conditions in larger cities where it is becoming more and more difficult for students of plants, even in schools to study our native plants, a book such as this becomes not only useful but neccessary. There was a time when cultivated plants were not studied as they should be: now they are often the only ones easily obtainable. Moreover it is desirable that we learn more about exotics as not a few become not merely adaptable to our climate, but even naturalized. One could name not a few that in the last generation became naturalized even among the woody plants. The "Manual" seems to be the most complete workable text available for the determination of the woody plants from other lands. The author therefore deserves our thanks for painstakingly working and describing these strangers to our country. It is a poor excuse for a botanist to dismiss a query about our plants of park and greenhouse by saying they are "cultivated" and therefore do not deserve study. Rehder by supplying us with this book, renders the excuse more specious than it ever could have been. Questions of nomenclature have apparently been left purposely to the field of controversy and this is plausible. Some species have been perhaps left out that might have been included but it is no small labor to make a handy volume of reference that contains as many up to date introductions from abroad and other parts of our country without making the volume too unwieldy for beginners. We consider the work as one of the most welcome to our shelves of any in recent years, inasmuch as it is what we surely have been longing for for many years. When much of our information of exotics had to be obtained labouriously and unsatisfactorily from plant and seed catalogues.—J.A.N.